Investigating conflict between threatened marine megavertebrates and Mediterranean small-scale fisheries

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

Abstract

Most fish stocks are being extracted at unsustainable rates and through bycatch, many marine megavertebrate species have unfavourable conservation status. The sheer number and diversity of small-scale fishing vessels worldwide presents a challenge to monitoring and research, therefore compared to industrialised fisheries, little is known about their activities or their sustainability. This thesis addresses this information gap by examining motorised polyvalent vessels <12 m length in the Mediterranean, which make up over 80 % of the fleet. We take North Cyprus as a case example to scrutinise interactions with marine turtles and dolphins. Marine turtle mortalities were found to be common (of the order of 1000 turtles caught annually; 60 % mortality), with trammel nets targeting Siganidae likely the greatest source of mortality. During the nesting season, breeding loggerhead turtles (*Caretta caretta*) were poorly protected from fishing pressure by a proposed Marine Protected Area, while both green (*Chelonia mydas*) and loggerhead turtles under-used areas within the reserve. After nesting in Cyprus, loggerhead turtles used foraging areas across the eastern Mediterranean, where they were impacted by a range of fisheries with small-scale fisheries likely leading to the mortality of three study animals. Dolphins frequented 28 % of set nets and small numbers were present in fishing areas year-round. Although infrequent, dolphin bycatch was considered to have population level impacts. A pinger was trialled but had no effect on interactions. Dolphin depredation cost fishers thousands of euro annually, while landings were estimated to be far beyond those previously reported. A tool was developed to provide spatiotemporal activity data on small-scale fisheries and this tool was used to demonstrate potential conflict between seabirds, sea turtles and protected habitats in MPAs and in a Marine IBA. The results presented using anthropological surveys, strand monitoring, onboard observation, telemetry, vessel tracking and acoustic monitoring, will be useful in developing fisheries policy for North Cyprus and in directing Marine Spatial Planning. Novel techniques developed will be relevant in addressing fisheries interactions with marine megavertebrates in small-scale fisheries globally.

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At the outset, nearly a decade ago, this PhD was always going to be self-funded. And in a politically isolated state, where international conservation bodies are hesitant to provide support, and where environment and research have been low on the agenda, fundraising was a big challenge.

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I met and married my wife Damla (who had conveniently just submitted her PhD) and we raised two boys on Cyprus, Toprak and Poyraz during my PhD. Of course, this was of significant hindrance, but I love them all dearly and I am grateful for Damla’s inspiration, encouragement and support and the welcome distraction of those boys. If not for putting roots down in Cyprus, the PhD might have been another story.

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Author's declaration of contribution to co-authored chapters/research papers

Chapter I: Strand monitoring and anthropological surveys provide insight into marine turtle bycatch in small-scale fisheries of the eastern Mediterranean.

In this chapter I described marine turtle bycatch rates and provided information on the demographic groups impacted. I also isolated specific metiers that were associated with particularly high bycatch. I set up monthly strand monitoring at a sample of beaches across the coast, established relationships with fishers through workshops which were organised by Damla Beton and Özge Özden. I undertook questionnaires at these workshops while Burak Ali Çiçek surveyed additional fishers who were unable to attend. I responded to calls of fishers and made port visits to inspect their marine turtle bycatch. I analysed the data and wrote the chapter under supervision of Brendan Godley and Annette Broderick. All authors reviewed and contributed to the final manuscript which was published in Chelonian Conservation and Biology in 2013.

Chapter II: Shelf life: Neritic habitat use of a turtle population highly threatened by fisheries.

I analysed available post-nesting loggerhead turtle tracking data and planned further tracking, targeting specific coastlines and size classes to provide a more holistic sample, deploying ten further transmitters over two nesting seasons. I received training from Alan Rees and Kimberley stokes in spatial analysis, to delineate and present the foraging habitats of Cyprus's nesting loggerhead turtle population. Burak Ali Çiçek, Wayne Fuller, Kimberley Stokes, Brendan Godley, Annette Broderick and Fiona Glen contributed to field work. The manuscript was written up under supervision of Brendan Godley and Annette Broderick. All authors reviewed and contributed to the final manuscript which was published in Diversity and Distributions in 2016.

Chapter III: Conflict between dolphins and a data-scarce fishery of the European Union.

In this chapter I set out to understand the occurrence of dolphins in Cypriot fishing grounds, which were a chief complaint of fishers due to net damages resulting from depredation. Acoustic monitoring gear (CPODs) was provided by Nick Tregenza and Matthew Witt, both of whom also provided training in analysis of resulting data. Burak Ali Çiçek helped with questionnaire surveys. The manuscript was written up under supervision of Brendan Godley and Annette Broderick. All authors reviewed and contributed to the final manuscript which was published in Human Ecology in 2018.

Chapter IV: Off-the-shelf GPS technology to inform Marine Protected Areas for marine turtles.

Here to address funding barriers to marine megavertebrate habitat use studies I trilled cheaply available off-the-shelf GPS data loggers as an alternative to Argos tracking or Argos-linked fast acquisition GPS tracking, on green and loggerhead turtles during the nesting season. The results of GPS tracking were relevant in advising conservation measures at the study site. Philip Bradshaw and I undertook much of the GPS field work while Wayne Fuller, Kimberley stokes, Brendan Godley and Annette Broderick were involved in deploying satellite transmitters. The manuscript was written up under supervision of Brendan Godley and Annette Broderick. All authors reviewed and contributed to the final manuscript which was accepted for publication and is now in press (28th Sept 2018) at Biological Conservation.

Chapter V: Assessing fishing intensity, resource dependency and marine traffic for small-scale fisheries operating in Mediterranean Marine Protected Areas and Marine Important Bird Areas.

Here I again used cheaply available GPS data loggers. This time to track 13 % of the Turkish Cypriot fishing fleet over two fishing seasons. The results were exceptionally high-resolution data layers and spatiotemporal information. The tool will be relevant in understanding fisheries impacts, monitoring and managing fisheries and designing marine installations and marine protected areas. Kristian Metcalfe provided script and training for handling spatial data files. I built the maps and wrote the manuscript under supervision of Brendan Godley and Annette Broderick. The manuscript is formatted for ICES Journal of Marine Science and will be submitted in 2019.

Introduction

Background to the study

The Mediterranean Sea is a global biodiversity hotspot hosting an estimated 7 % of the world's marine biodiversity, but is highly impacted by fisheries (Coll et al., 2010, 2011, 2014). The region hosts important populations of threatened marine megavertebrates including sea turtles (Casale et al., 2018), marine mammals (Bearzi et al., 2012) and seabirds (Ramirez et al., 2017). All of these taxa can be affected by bycatch, where they accidentally become caught in fishing gear leading to mortalities at rates that can have serious population level implications, and therefore contributing to conservation concern (Lewison et al., 2004; Coll et al., 2012).

This PhD thesis was conceived with the aim of assessing interactions between vulnerable marine megavertebrates and the small-scale polyvalent fishing fleet of North Cyprus, which hosts important breeding sites for threatened Mediterranean monk seal (*Monachus monachus*; Gucu et al. 2009), green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles (Broderick et al. 2002), Mediterranean shag (*Gulosus aristotelis*) and Auduin's gull (*Larus audouinii*; Ramirez et al. 2017) and has important marine habitat types including extensive *Posidonia oceanica* beds which are protected by a series MPAs and a Marine Important Bird Area (IBA).

The work began in the 2009/2010 academic year when I received a small grant from United States Agency for International Development to undertake workshops in ports across the coast. Here, I discussed with fishers their interactions with seabirds, cetaceans, seals and marine turtles. Questionnaires (Appendix I) were completed (based on Moore et al. 2010) by 126 vessel captains, with fishers from all ports contributing (Chapter I). Marine turtle and dolphin (*Tursiops truncatus*) interactions were found to be very common, while interactions with seabirds and seals occurred less frequently. As marine turtle bycatch and dolphin depredation are Mediterranean-wide problems (see below and chapters I to III), and given the apparent acute rates of interactions described by fishers, I chose to focus four studies on assessing fisheries interactions with these taxa through strand monitoring, anthropological survey, onboard observation, biologging and acoustic monitoring. A fifth chapter tracked the vessels themselves vis GPS, developing a tool for addressing uncertainty in small-scale fisheries while producing high resolution fishery footprints that will be useful in marine spatial planning.

Mediterranean sea turtles and bycatch

Long-term sea turtle nest protection schemes at nesting beaches in Cyprus and other Mediterranean countries appears to be offsetting population declines and contributing to a recovery in the number of nests laid annually (used as a proxy to the number of adult individuals; Casale et al., 2015) for the two populations of sea turtle that breed in the Mediterranean (*Chelonia mydas* and *Caretta caretta*; Casale et al., 2018). However, fisheries bycatch rates in the Mediterranean are among the highest in the world (Wallace et al., 2010) and addressing Mediterranean Sea turtle bycatch remains a priority (Casale., 2018). Although much information on sea turtle bycatch is available for the region, it is generally biased to industrialised fisheries and not collected in a systematic way. Mediterranean sea turtle bycatch data were reviewed by Casale (2011). Here, where available, fishing effort and sea turtle catch rates were combined and compared by sea area. Data from specific métiers were pooled into the four broad gear descriptions: bottom trawl, pelagic longline, demersal longline and set net. Although this review uses a number of assumptions to estimate sea turtle catch rates in areas where data were scarce, it is considered to be conservative in its estimates and is the best assessment of marine turtle bycatch for the region. The review estimates that 132,000 sea turtles are captured annually in the Mediterranean and that 44,000 of these captures result in mortality. Catch rates are highest in pelagic longlines (57,000 turtles per year) and trawl fisheries (39,000 turtles per year), but mortality rates in these gears are relatively low (30% and 20% respectively). Fewer turtles are considered to be caught in set nets (23,000 turtles per year) and on demersal longlines (13,000 turtles per year) but mortality rates for these gears are higher (60% and 40%, respectively) as are reproductive values of the turtles caught, since these gears are used close to shore, thus impacting larger turtles that have already completed their pelagic juvenile developmental phase. The prevalence of these latter gears among the Mediterranean fleet and the tendency for them to be associated with small-scale fisheries (SSF), which predominate (*ca.* 80% of all vessels; (FAO 2016)) and for which robust turtle bycatch data and studies are often lacking, is of concern. The

Casale (2011) bycatch review thus concludes that Mediterranean populations are most effected by bottom-set gears in neritic areas, by small-scale vessels and by fisheries in the eastern basin (the eastern basin hosts c70% of Mediterranean small-scale fishing vessels; FAO 2016) and that SSF should be the priority focus of further sea turtle bycatch studies and mitigation efforts.

Although very useful on a Mediterranean-wide scale the Casale (2011) review is broad in its use of fishing gear categories. The four different gear types addressed can themselves be broken down into sub-métiers. Set nets in particular are a complex group of gears and can target a variety of species during different seasons, across a variety of depths and areas. For instance, they can be composed of monofilament, multi-strand, light or heavy, trammel nets with inner and outer meshes or single mesh gillnets, set in waters as shallow as a few meters or at many hundreds of meters. Equally demersal longlines can be set by day, by night, using different baits and hook types. By assessing bycatch rates in these sub-métiers, in individual fisheries, mitigation development may become a smaller task, with industry impact prioritised to key gear-target-site combinations, and therefore garnering greater political support.

Small-scale fisheries in the Mediterranean are extremely diverse with many thousands of vessels and as many as 150,000 fishers (FAO 2016), all with slightly different fishing preferences. In industrialised fisheries many fishers are employed on small numbers of large vessels, often multiple vessels operate under a single company, using a low diversity of well-defined métiers. Reporting on and governing a small number of well-established large industrial enterprises presents, in many ways, fewer challenges than many thousands of polyvalent boats. The relative paucity of information regarding global bycatch in small-scale fisheries has come to light over the last ten years (Soykan et al. 2008) and increasingly, anthropological and community-based methods are being used to estimate the impact of SSF on threatened marine vertebrate taxa. However, most research into sea turtle bycatch in Mediterranean fisheries has focussed on the industrial sector using direct onboard observation (Laurent et al., 2001; Casale et al., 2004; Deflorio et al., 2005; Luccetti et al., 2016).

European Commission financed a project to assess bycatch in drifting longline and trawl fisheries of the Mediterranean countries of the EU (Laurent et al. 2001). Results of bycatch studies from onboard observations made through the project in bottom-trawl fisheries in the north Adriatic (Casale et al. 2004) and in swordfish and tuna longlines in the Ionian Sea (Deflorio et al. 2005), have since been published. More recently, Vessel Monitoring System (VMS) data from Italian trawl fisheries were analysed to overlay intense fishing areas with available sea turtle tracking data in the northern Adriatic to identify bycatch hotspots (Lucchetti et al. 2016). Well-established long-term positive participatory relations were used to develop a logbook scheme to successfully estimate catches and mortality (Casale et al. 2007), a form of self-monitoring.

Cambiè et al (2010) combined onboard observation, a fleet (vessel) census and questionnaire interviews in a mixed polyvalent SSF using driftnets, bottom-set gillnets and trammel nets, seines, surface longlines, bottom-set long lines and pots off Sicily. They found that 87% of vessels were not registered and fishing illegally. The same author (Cambiè 2011) used a self-monitoring approach where fishers volunteered to complete data sheets on caching turtles in trammel nets off west Sardinia. More recently, Lucchetti et al. (2017) used country-wide interviews and strand monitoring to assess loggerhead turtle bycatch for the entire Italian fleet, all vessel types and métiers, but did not investigate specific métiers to a resolution greater than the broad gear types defined by Casale (2011). Although not the chief subject of the study, anthropological studies in Amvrakikos Gulf, Western Greece found that sea turtle bycatch was an economic issue for fishermen (Gonzalvo et al. 2015). More detailed questionnaire surveys to assess the perception of sea turtle bycatch among fishers, were used on the island of Crete and found that bycatch mostly occurred in set nets (Panagopoulou et al. 2017).

On the South East coast of Turkey between Mersin and Iskenderun mid and bottom-trawl vessels were investigated using onboard observers and questionnaires (Oruç 2001). Godley et al (1998) undertook interviews in ports and concluded that sea turtle bycatch in SFF operating along the northern coast of Cyprus and the southern coast of Turkey, was a cause for concern. Israeli fisheries were investigated using a combination of onboard observation on trawl vessels and interviews with fishers (Levy et al. 2015). The study concluded that set nets and trawl fisheries were of chief concern for sea turtles with particularly high catch and mortality rates. In Egypt, Nada and Casale (2011) used 445 interviews to understand the level of bycatch and turtle killing, but did not undertake detailed analysis of métiers. In Tunisia Onboard observers have been used to investigate sea turtle bycatch among bottom-set longline (Echwikhi et al. 2012), set net (Echwikhi et al. 2010), surface longline (Jribi et al. 2008) and trawl fisheries.

Mediterranean bottlenose dolphins, bycatch and depredation

Common bottlenose dolphins (*Tursiops truncatus*) in the Mediterranean were the target of extermination campaigns until the late 20th century and hostilities towards this species in the region continue (Bearzi et al., 2012; Lauriano et al., 2009; Reeves and Notarbartolo Di Sciara, 2006). Reduced carrying capacity due to region-wide over-exploitation of fish stocks (which include key prey species) and incidental mortality in fisheries are important ongoing threats to the Mediterranean subpopulation (Bearzi et al. 2012).

In the Mediterranean, the common bottlenose dolphin depredates bottom-set nets of SSF operating in coastal waters of most countries including Cyprus (see chapter III and references therein). In all cases, dolphins reduce catch, cause tears in nets and are a subject of complaint by fishers. The majority of Mediterranean fishing vessels use set nets (Casale, 2011) making this gear the cornerstone of Mediterranean fishing. Given the apparent broad distribution of this issue, losses are likely to be of regional economic significance. Although it is known that dolphin depredation can cost thousands of euro annually (Brotons et al., 2008; Gazo et al., 2008; Lauriano et al., 2004; Rocklin et al., 2009), few studies have attempted to accurately estimate the economic cost of this behaviour to fisheries.

Even small numbers of dolphin deaths can have significant negative impacts on populations and this is particularly concerning for the Mediterranean subpopulation of this species which is estimated to contain just 10 thousand individuals, which is declining and therefore of elevated conservation concern (IUCN Redlist: Vulnerable; Bearzi et al., 2012).

Description of the study

Having coarsely assessed the interaction fisheries and marine megavertebrates in North Cyprus through questionnaire surveys, I planned five chapters.

Chapter I aims to understand specific areas and metiers of the Turkish Cypriot polyvalent fleet that are responsible for the greatest bycatch impact on marine turtles. It combines strand monitoring and anthropological survey to provide an account of the magnitude of marine turtle bycatch, the species, and life stages impacted. Through gathering data on individual metiers such as soak time, set depth, and seasonal use while also having fishers declare their bycatch, and establishing year-round patrols for stranded dead turtles, I was able to pinpoint the likely metiers associated with greatest bycatch impacts on marine turtle populations. The study thus provides data on bycatch by turtle species, with detailed information presented at a resolution greater than currently available for the majority of Mediterranean countries. For instance, set nets are broken down to trammel nets and gillnets of varying mesh sizes, used to target various fish species according to their seasonality and habitat preferences, with variable impacts on sea turtles reported accordingly. The data will be relevant to the Turkish Cypriot authorities in setting depth limits and for further research to mitigate marine turtle bycatch in these gears.

Chapter II builds on loggerhead turtle satellite tracking effort that began in North Cyprus in 2001 (Broderick et al. 2007) to estimate the fisheries impacts on loggerhead turtles that nest in Cyprus. Bringing the total sample size to 27, I deployed 10 transmitters on female loggerheads, minimising sample bias through targeting females nesting on all coastlines, of a broad range of body sizes, and nesting at different stages in the season including females nesting early in the season, which had previously been overlooked. Early nesters (loggerheads lay multiple clutches within a season) showed surprisingly low nest site fidelity, laying subsequent clutches in other countries hundreds of kilometres away. I analysed the telemetry data to delimit migratory corridors and foraging sites used by loggerhead turtles across the eastern Mediterranean and discuss the results in relation to known fisheries threats in the region. Tracking showed three turtles to have died during the study, which enabled the calculation of a minimum mortality rate which is novel. This was higher than expected for a long-lived marine megavertebrate and comparable to mortality rates published for other fishery-impacted marine turtle populations. The study aimed to provide relevant data for coordinated international efforts to mitigate bycatch of adult loggerhead turtles.

Chapter III uses questionnaire data resulting from workshops at the outset of my PhD to understand the nature of dolphin depredation in Turkish Cypriot set net fisheries. I undertook onboard observations to test a pinger using experimental nets against control (no pinger) nets, while recording damage and comparing acoustic recordings at sets. The pingers did not have the desired effect of separating the dolphins from sets, and the dolphins continued to depredate with significant economic losses to the fishers. Complaints of fishers in losing thousands of euro annually to net damage caused by dolphins, were found to be justified. Static acoustic monitoring and onboard observations showed that dolphins were not transient but present at fishing grounds year-round, suggesting a small resident population and although annual bycatch was relatively low, its impact on this population is likely significant.

Chapter IV revealed the habitat use of loggerhead and green turtles during the inter-nesting period (the period of approximately 13d between depositing clutches on nesting beaches). I experimented with conventional off-the-shelf GPS loggers as an alternative to expensive Argos-linked fast-acquisition GPS technology which is usually used to track diving marine megavertebrates, due to the limitation of conventional GPS in requiring long surfacing periods (>35 sec) to provide locations. The devices provided sufficient data to advise on the boundaries of a Marine Protected Area proposed for the study site. Loggerhead turtles used areas just outside the reserve where they were not protected from threats such as fisheries pressure, while large areas within the reserve were under-used by both species. We also examined inter-nesting spatial data resulting from Argos satellite telemetry based post-nesting habitat use studies (Snape et al. 2016; Stokes et al. 2015) but found these data to be of poor resolution and not appropriate for defining fine-scale movements around nesting beaches. The conventional GPS technology is of relevance in tracking marine megavertabrates such as marine turtles, pinnapeds and penguins at breeding sites, where sufficient study animals can be recaptured for device retrieval and where funding barriers preclude the use of Argos-linked fast acquisition GPS.

Chapter V uses the same conventional GPS trackers used in chapter IV to track 13 % of the fishing vessels of North Cyprus, to provide data layers of fishing intensity, resource dependency and marine traffic, extrapolated to the national fleet. Fisheries maps for these parameters are overlaid on MPA and Marine IBA boundaries in the Karpaz Peninsula, revealing inadequacies in the management of these reserves and potential impacts on breeding sea turtles, breeding seabirds and their habitats. These data layers will be of use in Marine Spatial Planning, assessing overlap with biodiversity, potential bycatch hotspots and resource competition between fisheries and threatened marine megavertebrates. Resulting vessel activity data will be relevant to assessing extraction and planning management to meet sustainability targets. The low cost of the technique developed during this study makes it applicable to small-scale fisheries globally, which is important as these fisheries are often not monitored due to the fiscal challenges of reporting on vast numbers of vessels.

Chapter I: Strand monitoring and anthropological surveys provide insight into marine turtle bycatch in small-scale fisheries of the eastern Mediterranean.

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Abstract

It has become widely recognised that a large gap exists in the global knowledge of fisheries due to the continued oversight of the small-scale sector. For populations of marine turtles restricted to the eastern Mediterranean, bycatch in small-scale fisheries is a concern. Using North Cyprus as a case study for the region, we use anthropological methods to estimate the magnitude of marine turtle bycatch, whilst presenting novel information on the marine turtle life stages utilising the coast and profiling the fishery itself. Our analyses suggest that as many as 1000 turtles may be caught annually by this fishery with an estimated mortality rate of 60%. Trammel nets were the main cause of marine turtle bycatch. Strandings coincided with setting of trammel nets targeting siganids (*Siganus luridus* and *Siganus rivulatus*) and the majority of bycatch registered by fishers were caught in these gears. We demonstrate a relatively simple approach to evaluating marine turtle bycatch providing information that will allow local authorities and conservation groups to direct further research and possible mitigation measures.

Introduction

Small-scale fisheries produce over half of the world's fish catch and support more than 90% of its fishers (FAO 2010). However, their social and economic contributions are underestimated (Zeller et al. 2007) which has led to their marginalisation and underinvestment when compared to industrialised fisheries (Jacquet and Pauly 2008; Alfaro-Shigueto et al. 2010; McCluskey and Lewison 2008; Peckham et al. 2007; Read 2008). As small-scale fishing vessels are highly numerous, diverse and widely distributed, they are difficult to survey, a major logistical constraint which has also hindered research (Moore et al. 2010; Soykan et al. 2008; Stewart et al. 2010). In a review by Jacquet and Pauly (2008), small-scale fisheries were described as the best option for sustainable use of fisheries resources. However, negative ecological impacts of small-scale fisheries are increasingly being reported (Shester and Micheli 2011) and some authors speculate that their bycatch of large threatened marine vertebrates could equal or exceed the contribution of industrialised fisheries (Alfaro-Shigueto et al. 2011; Gilman et al. 2010; Mangel et al. 2010; Peckham et al. 2007; Zydelis et al. 2009). Bycatch of threatened species in small-scale fisheries is therefore considered a research priority in order to quantify and prioritise the threats and to urgently develop and direct mitigation strategies to reduce further population declines (D'Agrosa et al. 2000; Gilman et al. 2010; Jaramillo-Legorreta et al. 2007; Soykan et al. 2008).

Populations of the loggerhead (*Caretta caretta*) and green turtle (*Chelonia mydas*) are believed to have declined considerably in the Mediterranean due to a multitude of threats, chiefly fisheries mortality and loss of nesting habitat (Casale and Margaritoulis 2010, IUCN redlist of threatened species 2004). The Mediterranean green turtle was previously regarded by the IUCN Marine Turtle Specialist Group as a critically endangered regional sub-population (Broderick et al. 2006; Mast et al. 2006, Mrosovsky 2006), largely on account of its genetic isolation and distinctiveness from its global population. A recent global assessment of conservation priorities for marine turtles undertaken by Wallace et al. (2011) recognised the Mediterranean loggerhead and green turtles as regional management units and assessed them as being under high threat and therefore in need of targeted conservation action.

The Mediterranean loggerhead turtle population is estimated to contain 2000-3000 nesting females annually which are found nesting predominantly in Greece, Turkey, Cyprus and Libya (Casale and Margaritoulis 2010). The Mediterranean green turtle population is estimated at 300-400 nesting females annually, found nesting predominantly in Turkey and Cyprus (Broderick et al. 2002; Casale and Margaritoulis 2010). North Cyprus supports roughly 9% of the Mediterranean's nesting female loggerhead turtles and 28% of the basin's nesting female green turtles, making this a significant breeding ground for both species in the region (Broderick et al. 2002; Casale and Margaritoulis 2010).

A recent global analysis of marine turtle bycatch by Wallace et al. (2010) highlighted the Mediterranean as an area where marine turtle populations are particularly threatened by fisheries, warranting urgent conservation action. Here, an estimated 132,000 marine turtles are captured and 44,000 die annually as a result of fisheries interactions (Casale 2011). Small-scale fleets in the eastern basin are thought to pose the greatest threat to Mediterranean populations, as they operate close to nesting sites and so may take many breeding adults (Casale 2011). In 1998, marine turtle bycatch was highlighted as a cause for concern in North Cyprus and Turkey (Godley et al. 1998). One decade on we describe the bycatch problem in greater detail providing information that will contribute to the establishment of priorities needed for conservation strategies. In this study, our objectives were to a) quantify the threat of small-scale fisheries bycatch to marine turtles in North Cyprus, b) ascertain which turtle life-stages are most vulnerable, and c) describe specific aspects of the fishery that might have the greatest impact on affected sea turtle populations.

Methods

Strandings

From 1st November 2009 until 31st October 2011 we systematically monitored a series of 16 beaches totalling 14km in length around the coast of North Cyprus (Fig. 1). During the nesting season, (May 21st to October 5th), volunteers patrolled beaches at least once every three days as part of a long-term marine turtle monitoring project (Broderick et al. 2002). Outside the nesting season, volunteers patrolled beaches monthly. Volunteers also responded to public sightings across the coast. Upon finding a stranded turtle carcass, notch to notch curved-carapace length (CCL) was measured, photographs were taken, the carcass was checked for flipper tags, and the state of decomposition and any obvious injuries were noted. After recording, all carcasses were removed or marked with paint and/or buried *in situ* to prevent double recording. Data and images were uploaded by the recording volunteer to the international Sea Turtle Rehabilitation and Necropsy Database (www.seaturtle.org/strand) where they were checked and confirmed by the lead author.

Stranded carcasses were assigned to three maturity classes according to adult nesting female data from North Cyprus (Broderick et al. 2003) where female loggerhead turtles ranged from 63 to 87cm (mean=73.6) and female green turtles ranged from 77 to 106cm (mean=91.5). For their respective species, those carcasses below minimum nesting size were classed as juveniles, those between minimum and mean nesting size were classed as potential adults and those above mean nesting size were classed as adults. However, as size at maturity is expected to vary between sexes (Casale et al. 2005) and genetic origin (Casale et al. 2009) and as these parameters were not recorded for our carcasses, our categorisation serves only as relatively coarse guide to the reproductive value of stranded individuals, adults representing a greater loss than juveniles, being better established, less likely to be predated and closer to their optimum fecundity.

Fisher surveys to characterize fisheries and bycatch

During May, June, and July 2010, we carried out a programme of seven workshops in the main fishing harbours in North Cyprus (Fig. 1). Our objective was to gather data on the artisanal fishers using a written questionnaire (*sensu* Moore et al. 2010). Fishers completed questionnaires (Appendix I) and organisers answered any queries they had to provide clarification on specific sections. A total of 91 fishers completed questionnaires in this format. Further one-to-one questionnaire surveys were undertaken in the fishing harbours where an additional 49 fishers were interviewed using the same questionnaire between May and September 2011 (Table 1, Fig.1). Qualitative information was also recorded resulting from informal discussions held with fishers at workshops and in ports on their boats where they were able to illustrate their gears more clearly.

Vessels were counted in all fourteen harbours during July 2011 (Fig. 1, Table 1). As most vessels are active between dusk and dawn, our counts were made during afternoons, when the majority of vessels are in the harbours. Boats were classified as active or non-active according to the presence and readiness of gear onboard. These data were compared with government statistics for vessel and fisher numbers (Table 1).

The content of our questionnaires reflected queries developed during small informal preliminary workshops held prior to the study with fisheries cooperative leaders. Fishers were asked to indicate the months during which they were actively fishing and the months during which they had encountered marine turtle bycatch for the previous twelve month period. They were asked how many turtles they had caught during the previous 12 month period and of these how many had been returned to the sea alive. They were asked to indicate the gear type in which turtles were caught most regularly. In cases where these gears were gillnets or a trammel nets they were asked to specify the mesh size that most commonly caught turtles. For trammel nets the mesh size given refers to the inner-netting rather than the much larger outer-netting.

In a separate questionnaire (Appendix I), fishers were asked about the configurations of the sets they used for different target catch species and were asked to list the usual depth, distance of set from shore, set time, haul-time and mesh size for the main target species groups. They were also asked to indicate the months during which these gears were most commonly deployed.

Voluntary bycatch reporting

All fishers we approached were asked to contact the lead author by telephone on catching a turtle, either dead or alive, so that an inspection could be made and/or details of capture recorded. For most of these reports we confirmed species and CCL through inspection (Table 3 and 4). Specimens were separated into maturity classes by the same method as described for stranded carcasses. Fishers were asked to explain the gear specifications, target catch, depth of set and soak time for each turtle caught and they were asked whether the turtle was dead or alive on hauling (Table 3 and 4).

Results

Strandings

During the stranding study period (Nov 2009–Oct 2011), 129 marine turtle carcasses were recorded. Of these 50% were loggerhead turtles, 46% were green turtles and for 4% the species was not identified. Size-class frequency data for carcasses were compared with those for breeding adult females recorded at Alagadi nesting beach (Fig.1) during 2009-2011 (Fig. 2). The mean CCL of loggerhead turtle carcasses was 65cm (±SD=9cm). Thirty eight percent were juveniles, 47% were potential adults and 15% were adults. The mean CCL of green turtle carcasses was 47cm (±SD=15cm). Ninety six percent were juveniles, 2% were potential adults and 2% were adults. Just one carcass was flipper tagged, a female loggerhead turtle which had been tagged during nesting on June 12th 2011 was found dead on July 15th 2011.

Four loggerhead carcasses had clearly been caught on longlines. These four carcasses had hooks either in the mouth, through the mouth with line trailing from the cloaca, or in the flipper. All longline gear was typical of local bottom-set longlines using medium sized hooks (typically 30mm total length, 13mm gape "j" hooks (Beverly 2009)). For the remaining carcasses no cause of death was ascertainable.

Temporal patterns of marine turtle carcass reports were largely comparable between species (Fig. 3a and Fig. 3b), with relatively few carcasses reported during winter and increased numbers during summertime, peaking in June.

Fisher surveys to characterize fisheries and bycatch

The agricultural report of the Turkish Cypriot authorities (TRNC 2010) states that 447 vessels were registered in 2010 of which 300 were active (Table 1). We counted 342 vessels of which 215 were active in July 2011 (Table 1). As some vessels are said to be brought to the harbour by trailer, the quoted total of 300 active vessels (TRNC 2010) is plausible. Thus, we use this figure as the upper limit and the number of active vessels we counted as the lower limit to estimate a range of 215-300 active vessels. The captains of 126 vessels completed questionnaires (Table 1). Thus we estimate that through this study we acquired data on 42-59% of the active vessels in our study area with significant contribution from all of the harbours. However, as not every respondent answered every question, our sample sizes vary among questions.

All the vessels registered with North Cyprus authorities are less than 12m long and no vessels are permitted to use non-static gears. No industrialised vessels or non-static gears were observed in ports. Forty four percent of captains (n=124) fish throughout the year and more than 80% are active from April through October (Fig. 3c). Peak activity is during May when 95% of those surveyed claimed to be active. Eighty seven percent regularly used bottom-set nets (gill nets and/or trammel nets), 68% regularly used longlines and 55% regularly use both (n=101). The most common mesh size used by fishers for bottom-set nets was 18mm, with a range of other mesh sizes between 24 and 32mm also commonly used (Fig. 4a). Mesh sizes greater that 24mm were soaked for markedly longer periods than mesh sizes smaller than 24mm (Fig. 4b). During discussions fishers stated the reason for this was that large fish are able to survive entanglement for longer periods, whilst small fish died quickly and so spoiled during longer soaks.

Temporal data for the main bottom-set net fisheries are presented in Figure 5. Siganids (*Siganus luridus* and *Siganus rivulatus*) (Fig. 5a) are fished throughout the year but most intensively during June to August. Bogue (*Boops boops*) is also fished most heavily during the summer months (Fig. 5b). Picarels (*Spicara smaris* and *Spicara maena*) have a relatively narrow fishing season from February to May (Figure 5c) and red mullets (*Mullus surmuletus* and *Mullus barbatus barbatus*) are fished relatively heavily and consistently throughout the year, particularly from March to April (Fig. 5d). Details of the depth, distance from shore, soak time and mesh sizes used for the four most commonly fished groups are presented in Table 2.

In discussions with fishers in harbours they indicated that nets targeting red mullets and siganids are always trammel nets and that single panel gillnets were used for picarels and bogue. The outer-netting mesh size for trammel nets is determined by multiplying the chosen inner mesh size by a factor of 4-5. All nets seen were made from monofilament or multistrand nylon materials and both material types were seen for trammel nets and gillnets. Longlines were organised and stowed around baskets which would typically stow 200-300 hooks. Fishers indicated that all longlines used were set on the benthos to target groupers and porgies (Epinephelinae and Sparidae) and that baskets would be set and hauled within one fishing trip, often whilst bottom-set nets were being soaked. Some fishers stated that they switched to only longlines when net catches were low or when net and catch damages associated with depredation by dolphins were high. Two fishers in our study explained that surface longlines targeting swordfish were occasionally used by a few of the fishers in North Cyprus though these were not detailed in our questionnaire results. Sixty six percent of captains (n=117) claimed to have caught ≥1 turtles during the previous 12 months. Of these the median number of turtles caught was 5.5 (Inter-quartile range (IQR) 3-12.5) with a median of 4 (IQR 2-10) (73%) of these released alive. Amongst the remaining 34% of captains, it was not possible to separate true negative results from false negative results so we assume in our extrapolation that they caught no turtles. We thus extrapolated the median annual bycatch of 5.5 turtles per year to 66% (the proportion of or sample of captains who responded affirmatively) of the estimated 215-300 active vessels (i.e. 142-198 vessels) to estimate a range of 780-1089 turtles. Thus it is likely that of the order of 700-1100 turtles are captured annually in North Cyprus.

Most fishers indicated that their marine turtle bycatch was highest during summer months, specifically May-August (Fig 4d). Of 77 fishers who provided information on gears associated with bycatch 94% confirmed bottom-set nets and 14% confirmed longlines. Of those fishers who claimed to have caught marine turtles in bottom-set nets the median mesh size indicated was 28mm (IQR 20-32, range 18-100, n=28).

Voluntary bycatch reporting

From June 2009 to July 2012, 8 loggerhead turtles and 20 green turtles were registered by fishers with the lead author (Tables 3 and 4).

Registered loggerheads were caught at a median depth of 20m in bottom-set trammel nets (62.5%) and on bottom-set longlines (37.5%). The majority of trammel nets were targeting siganids whilst all other trammel nets and longlines targeted groupers and porgies. The mean CCL of loggerheads was 70.3cm (±SD=13.7cm) and the majority (75%) were potential adults. Three of five loggerheads caught in trammel nets died equating to a minimum mortality rate of 60% for loggerhead turtles caught in these gears. One fatality was dead on hauling and 2 died on inspection between 30 minutes to 1 hour post-haul. One surviving turtle was released alive by the fisher on hauling and one was deemed fit to be released on inspection. Of three loggerheads caught on longlines two were released alive by the fisher on hauling. Both were released with hooks in the mouth and throat and with monofilament snoods estimated at 30cm and 60cm (respectively) trailing from the mouth. Another was deemed fit for release on inspection after a hook was removed from the rear flipper.

Green turtles were all caught in bottom-set trammel nets at a median depth of 14m, the majority (89%) of which targeted siganids (Table 4). Mean CCL of these was 36.9cm (±SD=12.4cm) and all were juveniles. Twelve were dead on capture equating to a minimum mortality rate of 60% for green turtles caught in trammel nets. Five were released on inspection, one of which was not able to dive. Three were released alive by the fisher on hauling.

Discussion

Through a combination of ecological and anthropological data collection methods, this study provides a current assessment of marine turtle bycatch in North Cyprus. We also presented the first detailed descriptions of the commonly used gears and their relative threats to marine turtles, which are crucial pieces of information when considering priority gears and areas for mitigation. We provide the first insights into the importance of North Cyprus's coastal marine habitats for small to medium sized juvenile green turtles and large juvenile loggerhead turtles, revealing an interesting discrepancy in vertical habitat use, with the former apparently occupying shallower benthic waters. Although North Cyprus is a well-documented nesting site, no literature describes foraging habitats, which clearly must exist to support these size classes.

We presented circumstantial evidence from multiple sources indicating that there is a high likelihood that many of our stranded carcasses died through entanglements in or interactions with bottom-set trammel net gears, specifically those targeting siganids. Temporal patterns of siganid fishing mirror temporal stranding patterns and fisher descriptions of marine turtle bycatch seasonality (Figure 3). Fishers themselves indicated in questionnaires that most turtles were caught in bottom-set nets of mesh sizes typical of those used to target siganids. Most compelling is that the majority of turtles registered with us were caught in these gears and that size frequencies were fairly consistent between stranded carcasses and registered bycatch (Tables 3 and 4).

Some of the characteristics we describe for siganid trammel nets may make them more dangerous to turtles than other gears. For example, siganid nets are set in much shallower water and closer to shore than other nets (Table 2). They are thus more likely to overlap with known marine turtle habitats. Behavioural studies have shown that both foraging (Broderick et al. 2007; McClellan and Read 2009) and nesting (Fossette et al. 2012; Hays et al. 2002; Hochscheid et al. 1999; Houghton et al. 2002; Schofield et al. 2009) loggerhead and green turtles typically inhabit shallow coastal habitats. Although behavioural studies of juvenile turtles are lacking for North Cyprus, our bycatch data suggest they also occupy shallow benthic habitats. Mesh size may also play an important role in entanglement, particularly as siganid nets are always trammel nets with large outer-panel mesh sizes. Also, as mesh size seems to regulate soak time (Figure 4), the probability of turtles encountering siganid nets and being held beneath the surface for long durations is probably greater than for other small mesh gears. Further research might reveal useful associations between mesh size and size class of turtles taken as bycatch in this type of fishing gear.

Although fishers claimed in questionnaires that most turtles were released back to the sea alive, the likelihood of survival of these individuals is uncertain as a number of post-release turtle mortalities are likely to occur (Lutcavage and Lutz 1991). Recent research in similar fisheries of North Carolina (USA) suggested that up to 30% of turtles that survived gillnet entanglement died post-release (Snoddy and Southwood 2010). The reported bycatch data we presented include two loggerhead turtles which were alive on hauling but which subsequently died on inspection and two loggerhead turtles caught on longlines that were released at sea with entanglements that likely caused their death (Chaloupka et al. 2004). Because these "doomed" turtles would have been included in our questionnaire derived estimates of numbers returned to the sea alive, our questionnaire derived mortality rates are clearly underestimates. Bycatch reported by fishers show a minimum mortality rate of 60% for both species when entangled in trammel nets and data for longlines suggests a similar post-release mortality rate where fishers do not employ best practices for disentanglement. Therefore, of the 800-1100 turtles we estimate are caught annually, between 480 and 660 are probably killed.

Whilst there are uncertainties in our annual bycatch extrapolation (e.g., the true number of active vessels), we are confident that the magnitude of our estimates is correct. Furthermore, these estimates should be considered conservative because false negative results (where fishers chose not to disclose their bycatch estimates) were not included in our captures extrapolation, and because the fate of released turtles was not fully quantified.

One weakness of our strandings survey was that we were unable to match our spatial coverage of the fishery. Stranded carcasses from areas surrounding our survey beaches are therefore better represented than other areas where vessels are greater in number.

As a well-documented nesting site for both loggerhead and green turtles, one might expect to see adults of both species as incidental bycatch in North Cyprus, particularly, as fishing effort is highest just prior to the onset of and throughout the nesting season. Nesting data for adult green turtle females show that nesting female numbers in North Cyprus during 2010 and 2011 were among the highest in 19 seasons (Marine Turtle Research Group unpublished data); however few adult carcasses stranded. Since they are apparently present in coastal waters at the same time, differences in the habitat use patterns of adult and juvenile green turtles relative to fishing gears in use might render juveniles more susceptible to gillnet entanglement than adults. There is some evidence amongst behavioural and dietary studies to support this. Of 10 nesting female and one breeding male green turtles tracked from Alagadi, none remained in Cypriot waters after the nesting season (Broderick et al. 2007; Wright et al. 2012). Three further studies undertaken at Alagadi have shown that during the nesting season, gravid green turtles spend the majority of their time in waters ≤5m depth which would put them above the depth range of the shallowest set gillnets used by fishers in North Cyprus, including siganid trammel nets (Fuller et al. 2009; Hays et al. 2002; Hochscheid et al. 1999). Green turtles are thought to progress from pelagic zooplankton foraging to omnivorous neritic feeding, becoming increasing herbivorous as they grow older, but maintaining a mostly omnivorous diet throughout their juvenile lives (Cardona et al. 2009). This is supported by recent work using stable isotope analysis from turtles of the eastern Mediterranean including Cyprus (Cardona et al. 2010). In one harbour during 2010, 2011 and 2012, we recorded two juvenile green turtles being hand-fed discards by fishers

(Robin Snape personal observations). Juvenile green turtles are known to scavenge discards elsewhere (Cardona et al., 2009) and this behaviour might lead them to depredating from static fishing gears, making them more vulnerable than their adult counterparts to entanglement.

A paucity of lower size classes of loggerheads has previously been noted in North Cyprus waters (Godley et al. 1998) and this is substantiated in our results, where very few loggerheads encountered were below 50cm CCL. In Greece, adult males and female loggerheads tracked up to a month prior to and during nesting primarily used shallows ≤5m deep within 500m of the shore (Fossette et al. 2012; Schofield et al. 2009). Time depth recorder (TDR) studies at Alagadi have shown nesting female loggerhead turtles to use benthic waters less than 20m deep (Houghton et al. 2002) with significant periods spent within depths at which siganid trammel nets might be encountered.

To address conservation concerns through the development and implementation of mitigation strategies, it is important to know that numbers of caught turtles are indeed large enough to significantly impact specific populations and hence merit investment. At the population level, we assume that our bycatch turtles are all from Mediterranean breeding stock. But how do we decide which species is most at risk and so where to further prioritise research? Loggerhead turtles in the basin are more widespread, greater in number and are reported to be under less threat and at lower risk than green turtles (Wallace et al. 2011). Our data suggest that perhaps fewer loggerheads are taken in North Cyprus waters than are green turtles. One might therefore conclude that the most immediate concern would be the bycatch of green turtles. But when the size (CCL) of our samples are taken into account, the net fisheries impact on the loggerhead population may rival or exceed the impact on the green turtle population in terms of its overall deleterious consequences, as the loggerheads we recorded were likely closer to their optimum fecundity and better established than green turtles, their relative value to that population therefore being greater. Whilst we did not calculate true reproductive values for the specimens we encountered, as per Wallace et al (2008), such an approach might be useful in further prioritising conservation action between loggerhead and green turtle populations. At the rookery level, adult and juvenile loggerheads and juvenile green turtles from the relatively large rookeries of both species in Turkey or elsewhere in the Mediterranean may migrate to North Cyprus waters to forage making up a proportion of those turtles impacted here. A haplotype identification program for stranded and caught turtles to ascertain which rookeries are most impacted by the North Cyprus fishery might further aid conservation decisions.

Still, implementation of mitigation measures in small-scale fisheries presents a great challenge as fishers naturally prioritise their own needs above the requirements of governing bodies or the requests of conservation groups. Enforced regulation is difficult to achieve where fishers operate alone and are often too numerous to deploy enforcement officers. A recent study however, has shown some success in persuading fishermen to adopt bycatch reduction technologies, where a positive human context has been created and where fishermen have actively participated in research (Piovano et al. 2012). Also, although the structures of small-scale fisheries can hinder our understanding of them, their social systems have been utilised to promote cooperative management between governments and fishers (Campbell et al. 2009). Many of the fishers we approached in our study are concerned about marine turtle bycatch and were saddened when they had found dead turtles in their nets. The majority believe that turtles depredate fish from their nets causing significant financial losses and so would likely be open to experimenting with and using methods that reduce these incidents. Fishers certainly became more cooperative with repeated contacts, particularly when their efforts to report turtles were covered favourably in local media.

In terms of reducing marine turtle bycatch at a local level, this study has allowed us to establish specific priorities for mitigation in North Cyprus. Of the gears we studied, it would appear that further detailed scrutiny of the siganid fishery could yield the greatest dividend in reducing bycatch of either population. Onboard observers could now be used to compare marine turtle bycatch in siganid trammel net sets with bycatch in sets for other target catch in order to ground-truth our survey results. A number of marine turtle bycatch reduction strategies have been tested for static gillnets (Gilman et al. 2010) i.e. low-profile nets and illuminating nets with green LED lights (Wang 2010), which could be tested in North Cyprus. Certain expenses, including net materials, are subsidised by the North Cyprus authorities, so governance could be implemented through a top-down solution wherein governmental practices impact the magnitude of turtle bycatch i.e. those gears that are shown not to impact turtles are preferentially subsidised. Potential impacts of such strategies must first be assessed from a wider ecological perspective. For example, in the Mediterranean *Siganus rivulatus* and *Siganus luridus* are both very successful lessepsian invader species (Hassan et al. 2003) and seagrass (*Posidonia oceana*) is an important part of their diet (Shakman et al. 2009), so reduction in siganid fishing effort in North Cyprus could increase seagrass grazing pressure. Seagrass meadows constitute an important neritic habitat for North Cyprus (Fuller et al. 2009a, 2009b, 2010a, 2010b) and are thought to be declining globally (Gonzalez-Correa et al. 2007).

In the wider eastern Mediterranean, a regional program of local studies is required to assess specific fishery characteristics at scales used in this study. We recommend that that the best way to achieve this would be through a combination of anthropological surveys similar to those outlined here and establishment of voluntary, fisher-based bycatch reporting schemes and long-term marine turtle strandings networks. Results of such studies would enable identification of the highest impact fishing gears with a high degree of resolution. Only when specific aspects of individual fisheries are examined can we then test and implement the most appropriate and effective mitigation techniques to reduce marine turtle bycatch.

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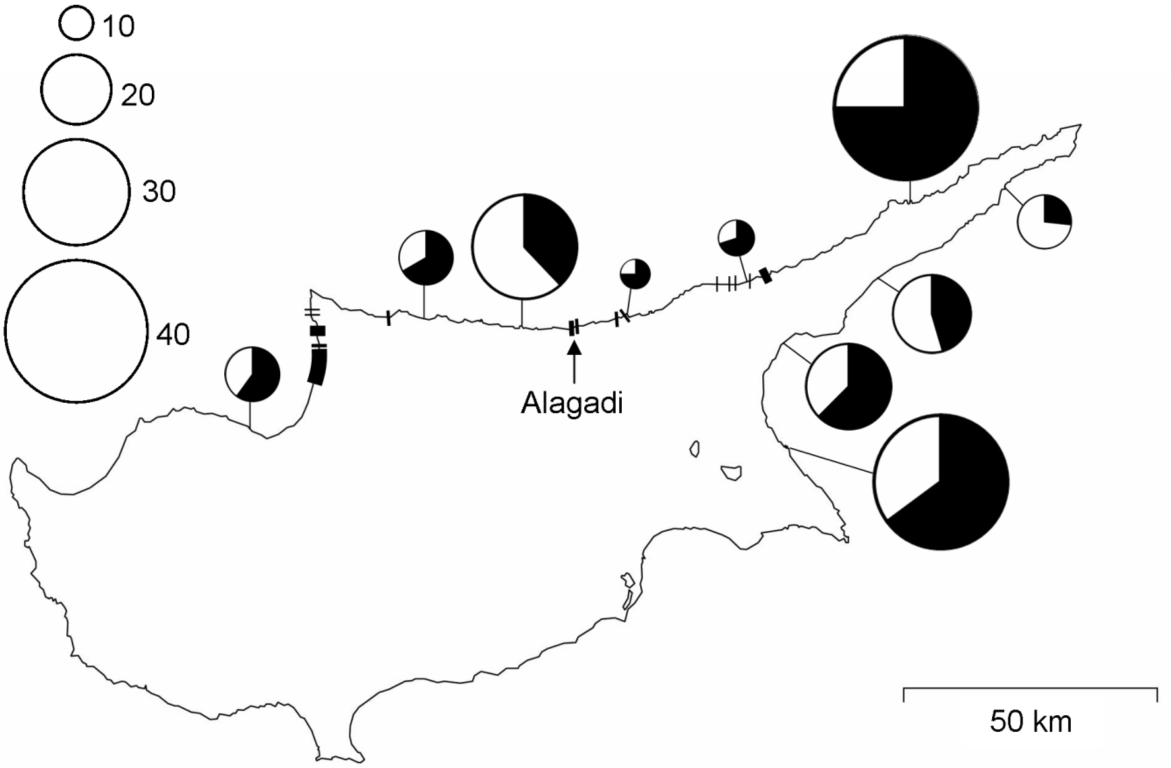

Figure 1. Map of study area in North Cyprus showing fishing harbour locations, proportions of vessels surveyed, beaches surveyed for carcasses and Alagadi study beach where size data for nesting females was collected. Black shaded coastline strips represent beaches surveyed for stranded carcasses. Additional carcasses were recorded from public sightings between Gemikonağı and Gazimağusa. Positions of fishing harbours are indicated by pie charts (clockwise from left Gemikonağı, Kayalar and Lapta, Girne, Alagadi and Esentepe, Tatlısu and Kaplıca, Balalan and Yeni Erenköy, Şelones, Kumyalı, Boğaz, Gazimağusa). Area of pie charts represents estimated number of active vessels scaled to the increments on left. Black fractions represent the estimated proportion of active vessels surveyed (Table 1).

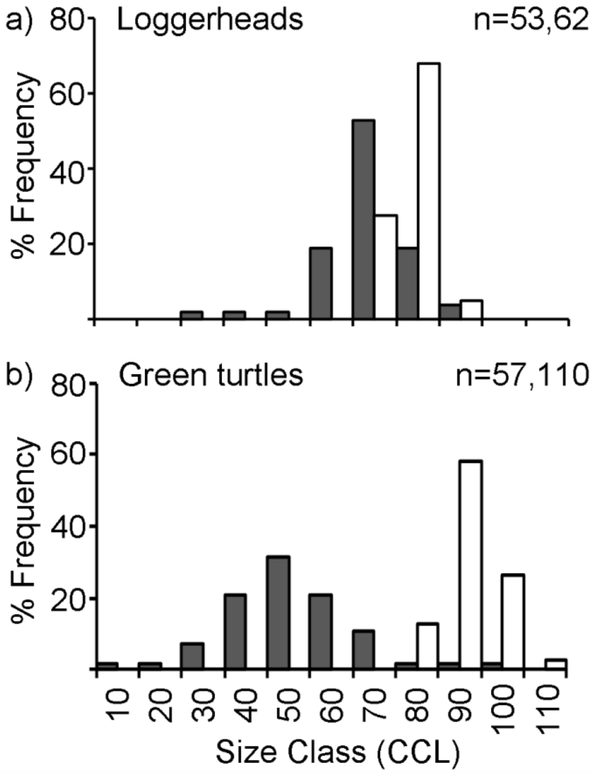

Figure 2. Size frequency histograms for a) loggerhead and b) green turtles in our study area. Shaded boxes represent stranded carcasses, open boxes represent adult nesting females recorded at Alagadi beach (2009-2011). n=number of stranded turtles, number of nesting females.

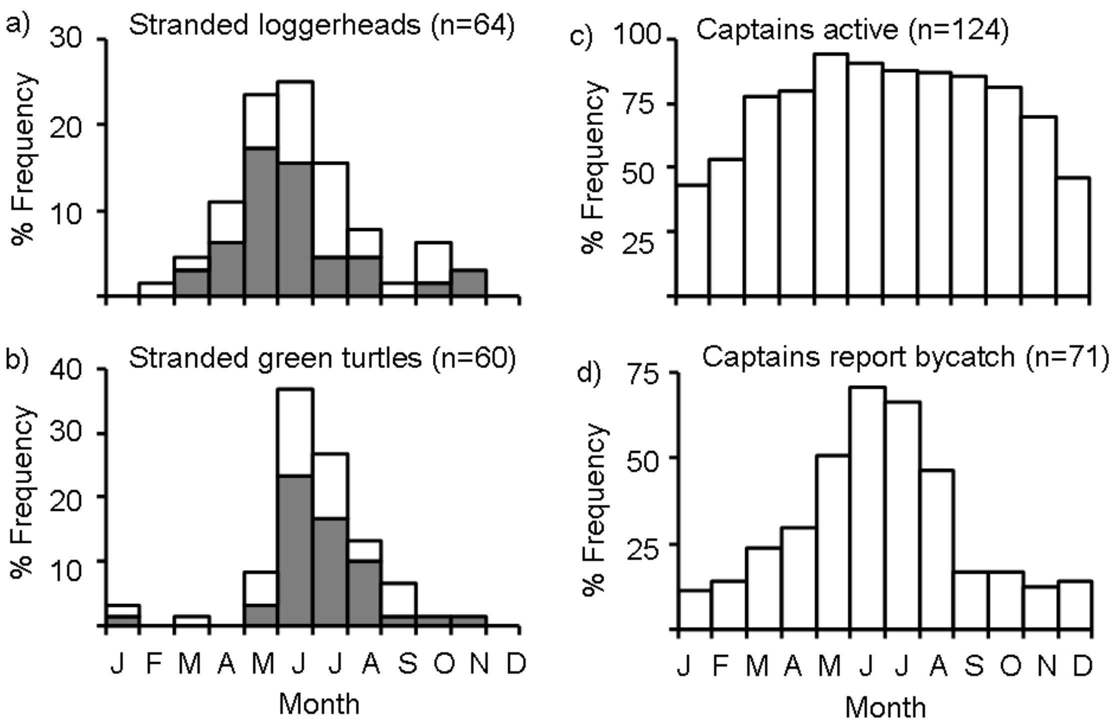

Figure 3. Temporal distribution of stranded a) loggerhead and b) green turtle carcasses. Shaded boxes show carcasses recorded on year-round study beaches, open boxes indicate carcasses recorded opportunistically and from public calls. Months of year during which captains stated in questionnaires that they c) actively fished and d) caught turtles.

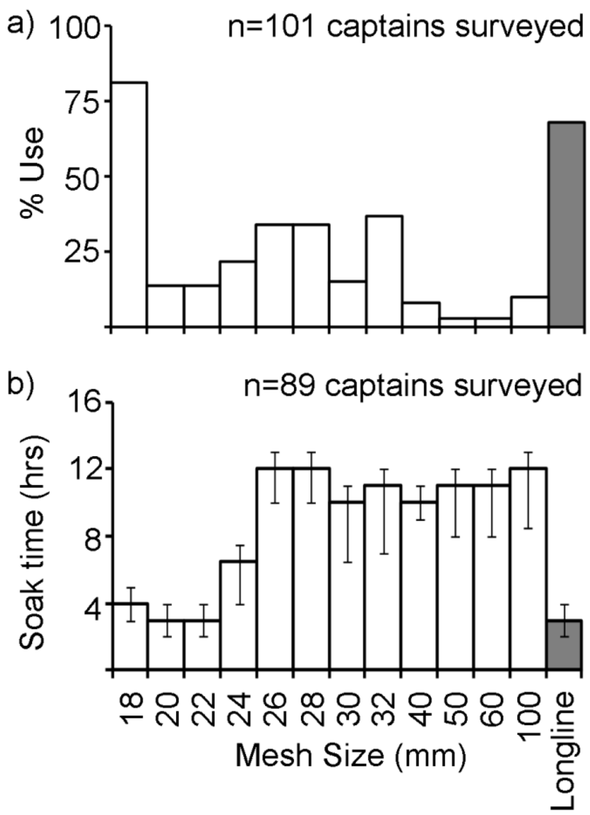

Figure 4. a) Percentage of captains using and **b)** soak time for various mesh sizes we recorded. Meshes <32mm are in 2mm bins, meshes >32mm are in 10mm bins. Shaded boxes represent bottom-set longlines. Error bars denote inter-quartile range.

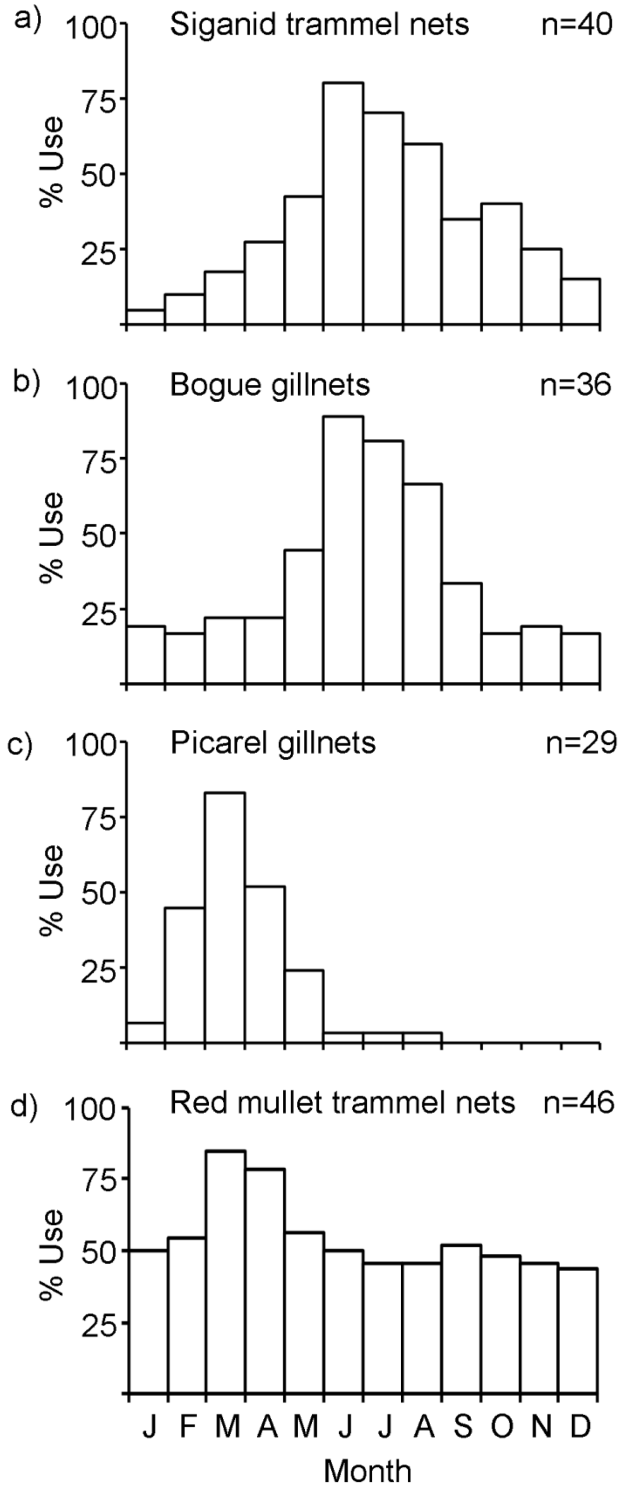

Figure 5. Percentage of captains using bottom-set nets by month for a) siganids (*Siganus luridus and Siganus rivulatus*), b) bogue (*Boops boops*), c) picarels (*Spicara smaris and Spicara maena*) and d) red mullets (*Mullus* spp).

Table 1. Fisher and fishing vessel statistics from government statistics (TRNC 2010) and from our 2011 surveys.

		Authority Report 2010			Our Survey 2011		
District	Harbour Name	Registered Fishers	Registered Vessels	Active Vessels	Total Vessels	Active Vessels	Vessels Surveyed
Lefkoşa	Gemikonağı				30	15	9
	Total	**62**	**60**	**43**	**30**	**15**	**9**
Girne	Kayalar				3	3	2
	Lapta				22	12	8
	Girne				60	29	11
	Esentepe&Alagadi				14	8	6
	Total	**110**	**115**	**73**	**99**	**52**	**27**
Gazimağusa	Tatlısu&Kaplıca				15	10	7
	Balalan				3	3	2
	YeniErenkoy				45	37	28
	Şelones				16	15	4
	Kumyalı				28	22	10
	Boğaz				41	24	15
	Gazimağusa				65	37	24
	Total	**238**	**272**	**184**	**213**	**148**	**90**
		410	**447**	**300**	**342**	**215**	**126**

Table 2. Depth, distance from shore, soak time and mesh size described by fishers for siganid (*Siganus luridus* and *Siganus rivulatus*) trammel nets, bogue (*Boops boops*) gillnets, picarel (*Spicara smaris* and *Spicara meana*) gillnets and red mullet (*Mullus* spp) trammel nets.

Target catch	Depth (m)				Distance from Shore (m)				Soak Time (h)				Mesh Size (mm^2)			
	Median, IQR, Range, (n)				***Median, IQR, Range, (n)***				***Median, IQR, Range, (n)***				***Median, IQR, Range, (n)***			
Siganids	15,	12-20,	5-42,	(47)	113,	50-225,	10-600,	(41)	11,	9-12,	3-15,	(48)	28,	28-30,	18-33,	(60)
Bogue	41,	40-45,	10-95,	(39)	400,	238-525,	50-4000,	(32)	3,	3-5,	1-7,	(41)	18,	18-19,	18-25,	(56)
Red mullets	41,	38-68,	10-180,	(62)	500,	238-813,	40-5000,	(52)	4,	3-5,	1-17,	(68)	18,	18-19,	18-23,	(85)
Picarels	40,	40-41,	38-43,	(7)	500,	275-500,	100-4000,	(7)	3,	1-3,	1-5,	(8)	18,	18-18,	16-21,	(24)

Table 3. Details of registered bycatch for loggerhead turtles between June 2010 and July 2012. DOI=dead on inspection, ROI=released on inspection, ROH=released on hauling, DOH=dead on hauling, ROH_E released with entanglement on hauling. Where turtles were released on inspection, they were deemed by the lead author to be fit for release.

Harbour	Date mm/yy	Fisher #	Inspection made?	Maturity class	CCL	State on hauling	Fate	Target	Gear type	Soak (hrs)	Mesh (mm)	Depth (m)
Lapta	06/10	10	Yes	PA	63.5	Alive	DOI	Porgies/Groupers	Trammel	12	32	
Kaplıca	07/10	2	Yes	PA	71	Alive	ROI	Siganids	Trammel		32	20
Lapta	11/11	10	By photo	J	60	Alive	ROH	Porgies/Groupers	Trammel	12	32	
Gazimağusa	06/12	6	Yes	PA	65	Alive	DOI	Siganids	Trammel	4	32	25
Gazimağusa	07/12	4	By photo	PA	65	Dead	DOH	Siganids	Trammel	10	26	20
Boğaz	07/12	13	No	PA	70	Alive	ROH_E	Porgies/Groupers	Longline	8		19
Boğaz	07/12	13	No	A	103	Alive	ROH_E	Porgies/Groupers	Longline	13		27
Boğaz	07/12	13	Yes	PA	65	Alive	ROI	Porgies/Groupers	Longline	11		18
				N	8				**n**	7	5	6
				Mean	70.3				**Median**	11	32	20
				SD	13.7				**IQR**	9-12	30-32	19-25
				Range	60-103				**Range**	4-13	26-32	18-27

Table 4. Details of registered bycatch for green turtles between June 2010 and July 2012. ROI=released on inspection, DOH=dead on hauling, ROH=released on hauling. Where turtles were released on inspection, they were deemed by the lead author to be fit for release, however, one individual released was unable to dive.

Harbour	**Date mm/yy**	**Fisher #**	**Inspection made?**	**Maturity class**	**CCL**	**State on hauling**	**Fate**	**Target**	**Gear type**	**Soak (hrs)**	**Mesh (mm)**	**Depth (m)**
Gemikonağı	06/10	0	Yes	J	60	Alive	ROI		Trammel			
Gemikonağı	06/10	1	Yes	J	27	Dead	DOH		Trammel			
Esentepe	06/11	3	Yes	J	27	Alive	ROI	Siganids	Trammel		28	9
Lapta	04/12	7	Yes	J	39	Dead	DOH	Siganids	Trammel		32	14
Lapta	04/12	7	Yes	J	36	Dead	DOH	Siganids	Trammel		32	14
Lapta	04/12	7	Yes	J	45	Dead	DOH	Siganids	Trammel		32	14
Tatlısu	05/12	3	Yes	J	26	Dead	DOH	Siganids	Trammel	13	32	10
Lapta	05/12	11	Yes	J	30.4	Dead	DOH	Siganids	Trammel		32	
Kaplıca	06/12	2	Yes	J	33.5	Alive	ROI	Siganids	Trammel	5	32	20
Lapta	06/12	11	Yes	J	27.4	Dead	DOH	Siganids	Trammel		32	
Lapta	06/12	11	Yes	J	31	Dead	DOH	Siganids	Trammel		32	
Lapta	06/12	11	Yes	J	26.9	Dead	DOH	Siganids	Trammel		32	
Lapta	06/12	11	Yes	J	28	Dead	DOH	Siganids	Trammel		32	
Gazimağusa	06/12	4	No	J	63	Alive	ROH	Siganids	Trammel	12	24	14.5
Lapta	06/12	7	Yes	J	33.8	Dead	DOH	Red mullets	Trammel	3	18	19
Y. Erenköy	06/12	8	Yes	J	29	Alive	ROI	Siganids	Trammel	11		8.5
Boğaz	06/12	13	No	J	58	Alive	ROH	Siganids	Trammel	3	20	3
Lapta	07/12	10	Yes	J	27	Alive	ROI	Porgies/Groupers	Trammel	12	32	38
Boğaz	07/12	14	No	J	55	Alive	ROH	Siganids	Trammel	4	28-32	6.5
Boğaz	07/12	14	No	J	34	Dead	DOH	Siganids	Trammel	4	28-32	6.5
				N	20				**n**	9	17	13
				Mean	36.9				**Median**	5	32	14
				SD	12.4				**IQR**	4-12	30-32	9-15
				Range	26-63				**Range**	3-13	18-32	3-38

Chapter II: Shelf life: Neritic habitat use of a turtle population highly threatened by fisheries.

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Abstract

It is difficult to mitigate threats to marine vertebrates until their habitat use is understood. We report on a decade of satellite tracking loggerhead turtles (*Caretta caretta*) from an important nesting site to determine priority habitats for their protection in a region where they are known to be heavily impacted by fisheries. We tracked 27 adult female loggerheads between 2001 and 2012 from North Cyprus nesting beaches. To eliminate potential biases, we included females nesting on all coasts of our study area, at different periods of the nesting season and from a range of size classes. Foraging sites were distributed over the continental shelf of Cyprus, the Levant and North Africa, up to a maximum distance of 2,100km from nesting sites. Foraging sites were clustered in a) near-shore waters of Cyprus and Syria, b) off-shore waters of Egypt and c) off-shore and near-shore regions of Libya and Tunisia. The North Cyprus and West Egypt/East Libyan coasts are important areas for loggerhead turtles during migration. Movement patterns within foraging sites strongly suggest benthic feeding in discrete areas. Early nesters visited other rookeries in Turkey, Syria and Israel where they likely laid further clutches. Tracking suggests minimum annual mortality of 11%; comparable to other fishery-impacted loggerhead populations. This work further highlights the importance of neritic habitats of Libya and Tunisia as areas likely used by loggerhead turtles from many of the Mediterranean rookeries and where the threat of fisheries bycatch is high. Our tracking data also suggest that anthropogenic mortalities may have occurred in North Cyprus, Syria and Egypt; all within near-shore marine areas where small-scale fisheries operate. Protection of this species across many geopolitical units is a major challenge and documenting their distribution is an important first step.

Introduction

Many marine vertebrate species have evolved to be long-lived, a strategy which can render their populations particularly sensitive to anthropogenic mortality (Lewison *et al*., 2004). Sea turtles, sharks, seabirds and marine mammals have been particularly impacted by man, mostly attributable to direct harvesting and/or fisheries bycatch, radically reducing many populations (Spotila *et al*., 2000; Clarke *et al*., 2013; Maxwell *et al*., 2013; Paleczny *et al*., 2015). If these anthropogenic threats are to be mitigated, the distribution of vulnerable populations must be understood. Aerial and ship-based surveys can be used to infer the relative abundance of species in specific areas of interest (Lauriano *et al*., 2011; Hammond *et al*., 2013; Hodgson *et al*., 2013). Large marine vertebrates, however, are usually highly mobile, exploiting habitats across wide, diverse and remote areas (Bowen *et al*., 1995; Robinson *et al*., 2009). For such taxa, studies using animal-borne tracking devices can yield ground-breaking insights into the wider ecology of the study species (Rodhouse *et al*., 1996; Croxall *et al*., 2005; James *et al*., 2006).

Sea turtles have been the subject of significant satellite tracking effort (Godley *et al*., 2008). A common finding is that, even among individuals of the same population, patterns of habitat use are heterogenous (Hawkes *et al*., 2006; Rees *et al*., 2010a). Sample sizes should ideally be large enough to capture such variation but are often constrained by the high cost of devices and satellite services. The results of investment in programmes of satellite telemetry over periods of many years, where cumulative costs are met in stages, are increasingly yielding dividends (Tucker, 2010; Griffin *et al*., 2013; Pikesley *et al*., 2013; Schofield *et al*., 2013).

The Mediterranean loggerhead turtle population can be regarded as functionally independent from other Atlantic populations (Laurent *et al*., 1998; Carreras *et al*., 2011), and has experienced declines in response to historical harvesting, fisheries interactions and coastal development (Casale & Margaritoulis 2010). As such, Mediterranean loggerhead turtles have been described as a Regional Management Unit that is at low risk but under high threat (Wallace *et al*., 2011). The IUCN (International Union for Conservation of Nature) recently classified the Mediterranean loggerhead subpopulation as “Least Concern” on the basis of an overall increasing estimated population, a relatively large distribution and a relatively large estimated population. This status, however, is entirely conservation dependant, since the increasing estimated population trend is the product of decades of intensive conservation efforts at nest sites and could be reversed should these efforts cease (Casale, 2015).

Fisheries bycatch is the greatest threat to loggerhead turtles globally and bycatch rates in the Mediterranean are among the highest in the world (Wallace *et a*l., 2010, 2011; Casale, 2011). Genetic analyses in the west and central Mediterranean, show that pelagic Mediterranean habitats are shared with loggerheads from populations nesting in the western Atlantic (Laurent *et al*., 1998; Carreras *et al*., 2006). However, bycatch samples from neritic fisheries throughout the basin rarely include western Atlantic haplotypes, suggesting that loggerheads from these distant stocks leave the Mediterranean, prior to a developmental shift to neritic habitats (Revelles *et al*., 2007; Carreras *et al*., 2011; Garofalo *et al*., 2013). Bycatch in neritic areas of the Mediterranean, therefore, predominantly impacts Mediterranean stocks; specifically, larger post-pelagic animals that are of higher reproductive value than pelagic juveniles (Wallace *et al.* 2008; Casale 2011; Snape *et al.* 2013). Management of this bycatch is, therefore, a priority and an understanding of the distribution of turtles is a clear prerequisite.

Studies published to date to investigate the habitat use of female post-breeding Mediterranean loggerheads, have focused on two of the main rookeries in Greece and Cyprus, whose coastlines support approximately 48% and 9% of nesting for this population respectively (Casale & Margaritoulis 2010). Key findings of these studies are that: (1) turtles show fidelity both to foraging sites and to migratory routes between breeding and foraging sites, (2) nearly all forage in neritic waters, aggregating in areas with wide availability of continental shelf and, (3) most turtles reside at the same foraging site for long periods (Godley *et al*., 2003; Broderick *et al*., 2007; Zbinden *et al*., 2011; Schofield *et al*., 2013). Here we aimed to provide a more holistic assessment of migratory corridors and key foraging areas, by extending our North Cyprus study (Godley *et al*., 2003; Broderick *et al*., 2007), incorporating a much larger sample size and deploying from a range of sites over the entire duration of the nesting season.

Methods

Twenty-seven adult female loggerhead turtles were tracked after nesting in North Cyprus (coastline of approximately 325km) between 2001 and 2012 (Table 1). The results of 10 of these deployments have previously been described by Godley *et al.* (2003) and Broderick *et al.* (2007).

As biases within and among seasons and across size classes are capable of producing dramatically misleading results (Hawkes *et al*., 2006; Rees *et al*., 2010a; Witt *et al*., 2011), our deployments were made over several years, were spread across nearly every week of the nesting season and across most size classes (Fig. 1). To reduce potential bias associated with nesting sites, turtles were tracked from nesting sites on every coast (Fig. 2a insert). PTTs were attached according to the protocol outlined by Godley *et al.* (2002). A variety of PTT models were used during the 11-year deployment period (Table 1). Prior to device attachment minimum curved carapace length (CCLmin; Bolten, 1999) was recorded (Table 1).

Location data were handled using Satellite Tracking Analysis Tool (STAT; Coyne & Godley, 2005). In order to eliminate erroneous data, location classes 0 (error >1.5km) and Z (failed Argos plausibility tests) and those inferring speeds of >5km h^{-1} (greater than expected swimming speeds for marine turtles; Witt et al., 2010) were removed. We visually inferred broad behavioural patterns, with all turtles undertaking clear post-nesting migrations to neritic foraging sites where they took up residency in discrete areas; a common strategy for loggerhead turtles, particularly in the Mediterranean (Luschi & Casale, 2014; minimum, this study: 27 days). Where turtles shuttled between more than one discrete area (centroids >10km distant), data were split and analysed separately.

To visualise the shape and approximate magnitude of core areas of habitat use, the "Kernel Density Estimator" command of Geospatial Modelling Environment (GME), was used to produce kernels for filtered foraging site data. Since size of kernels can be influenced by many factors other than the horizontal habitat use of the study animal (Witt *et al*., 2010), we did not seek to over-interpret and generate precise home range magnitude. We trialled a range of bandwidth levels and chose 0.0003, which we felt best described the shape of our data plots. The GME "Isopleth" command was used to map isopleths within kernels of 20% and

50% of the total data distribution to represent the shape of core foraging areas. Where turtles occupied multiple sub-sites, the number of days spent within and the total number of visits to each site were compiled (Table 1).

To contextualise the threat of fisheries bycatch to study turtles, we used available fisheries bycatch information (a comprehensive review by Casale, 2011) for the countries hosting foraging of >1 study turtle.

Device terminations were attributed to the mortality of a study turtle when preceded directly by: (1) a sudden increase in the rate of messages received from devices, indicating that the device was no longer submerged and (2) movement away from foraging sites, indicating a deviation from expected spatial habitat use (see Hays *et al.,* 2003; Snoddy & Southwood Williard 2010). An approximate annual mortality rate was calculated after Hays *et al.* (2003).

Results

Body size of turtles tracked to foraging sites ranged from 64-85cm CCLmin (mean ± SD: 72.1 ± 4.84cm; Table 1, Fig. 1). This is reflective of the size range previously reported by Broderick & Godley (1996) for this rookery of mean: 73.4cm (range: 65-86.5cm). Of the 27 study turtles, 24 individuals reached foraging sites where they remained for 27 days or more (Table 1, Fig. 2).

Inter-nesting movements and post-nesting migrations.

On leaving Cyprus, turtles took 6-86 days to reach foraging sites (mean ± SE: 32 ± 5 days). Twenty one of the 24 turtles tracked to foraging sites followed relatively direct trajectories during their post-nesting migrations (Fig. 2a). Three turtles (12.5%; turtles B, J and P; Fig. 2b-d) visited the coastlines of other countries during the nesting season. Turtle J, was equipped with a transmitter model which logged wet and dry periods through a salt-water switch. This device recorded and transmitted data for haul-outs periods on the Turkish coast (Fig. 2b). These periods were suggestive of nesting with internesting intervals of 17 and 12 days; consistent with internesting interval ranges recorded for loggerheads in Cyprus (Broderick *et al*., 2002). For the other two turtles of this group, we plotted likely nesting events according to clustering of location data coinciding temporally with expected nesting (Broderick & Godley, 1996) and spatially with known nesting sites (Casale & Margaritoulis, 2010; Fig. 2 c-d).

During open sea crossings, routes of individual turtles were relatively dispersed, but important coastal migration routes were determined along the coasts of Cyprus (including the British Overseas Territory Sovereign Base Area (SBA) Dhekelia) and along the coast of western Egypt and Libya (Fig. 2e).

Foraging Sites

Once at foraging sites, the depth of water and patterns of movement were suggestive of benthic feeding (Hawkes *et al*., 2006), with some (7 of 24) turtles shuttling between two or three sub-sites greater than 10km apart (Fig. 3, See Figure S1 in Supporting Information). In total, 32 foraging sites were mapped for durations ranging from 27-1405 days (Table 1). The median depth at locations for filtered Argos data at foraging sites ranged between 2-121m (Table 1). Eighty three percent of turtles foraged in three main regions: (1) close to deployment sites in Cyprus (including British Sovereign Base Area Akrotiri) and Syria (n=9; 38%; Fig. 3a), (2) at medium distance from deployment sites off Egypt (n=5; 21%; Fig. 3b) and (3) far from deployment sites along the western Libyan and the eastern Tunisian shelf areas (n=6; 25%; Fig. 3c). The remaining 17% were distributed diffusely across Libya (n=3) and one individual foraged in Lebanon (see Fig. S1).

Mortalities

Argos data from turtles F and K suggest that these individuals were caught at their foraging sites in depths of the order of 5 and 2 meters, respectively (Fig. 4, Table 1). The carcass of turtle AA was returned to us in North Cyprus 35 days post-deployment. These three deaths suggest an annual mortality rate of 0.11 (annual survival probability of 0.89) for our 9741 tracking days (Hays *et al.,* 2003).

Discussion

We present insights that collectively represent a significant step towards a holistic understanding of the habitat requirements of adult Mediterranean loggerhead turtles. These data will be of great value in targeting marine turtle-fisheries interaction studies that are required in order to develop strategies to reduce the threat of fisheries. Our work also provides the evidence of significant international movement of females among nesting sites of this population, which will have ramifications for the study of genetic structure, design of monitoring strategies and generation of population estimates.

Life history

As is the case for all Mediterranean nesting females tracked to date (Luschi & Casale, 2014), turtles all appeared to be neritic foragers, making relatively direct migrations to continental shelf sites after nesting. This is despite the fact that we specifically included small individuals that have been shown to exhibit pelagic foraging in other populations (Hatase et al., 2002; Hawkes et al., 2006). None made marked seasonal migrations between foraging sites to avoid winter temperature extremes, which contrasts with conspecifics using the Adriatic region of the Mediterranean (Schofield *et al*., 2013).

Migration corridors and foraging sites

Adult loggerhead turtle densities will be elevated in the migration corridors we describe here off Cyprus, western Egypt and eastern Libya during the post-nesting migration period in July and August. These overlap significantly with those of green turtles (*Chelonia mydas*) in the region (Stokes *et al*., 2015). Previously unreported foraging sites for this rookery were revealed on the Tunisian/Libyan shelf area, scattered along the Libyan coast, at Lake Bardawil, Egypt, off Lebanon and British Sovereign Base Area Akrotiri on Cyprus. The larger sample size here also emphasises the importance of foraging areas previously published by Broderick *et al*. (2007).

The most important foraging areas for Mediterranean loggerheads are now understood to be in neritic waters of the Adriatic, on the Tunisian/Libyan shelf, off the Nile Delta in Egypt, in Cyprus and in Syria. This broad and diffuse distribution poses a challenge to managing their conservation. Densities appear to be higher closer to nest sites in Cyprus, but one must consider that loggerheads from other rookeries will also be occupying the North African Coast and the Levant. More than a quarter of turtles tracked in this study used the Tunisian/Libyan shelf shared by a large proportion of turtles tracked from the Greek rookeries (Schofield *et al*., 2013; Zbinden *et al*., 2011). Nesting females subject to flipper tagging in Greece have been recovered in eastern Libya (1), Egypt (1), Israel (3) and Cyprus (2); Margaritoulis, 1988; Margaritoulis & Rees, 2011; Margaritoulis *pers. comm*).

The observed distribution of foraging sites may well be a product of a trade-off between the availability of suitable shelf habitat and the energetic costs of migrations. A pattern observed in our study in common with other loggerhead studies (Rees *et al*., 2010a; Schofield *et al*., 2010; Hawkes *et al*., 2011) was that foraging sites were generally larger in turtles residing off-shore (considered here to be where the 20% isopleth of the foraging site lies >10km from land) and in deeper water than those on the coast. Habitat utilisation in harbours and embayments was more discrete, clearly being restricted by physical boundaries. The fifty percent core utility areas appear to be of a similar magnitude as those proposed for Mediterranean loggerheads by Schofield *et al*. (2010) of tens to hundreds of square kilometres.

Multiple country nesting

Loggerhead females laying a single clutch in Cyprus have previously been shown to have low nest site fidelity (Broderick *et al.*, 2002). We confirm that these single clutch females were indeed likely to be subsequently nesting elsewhere. Loggerheads are known to exhibit relatively low nest site fidelity in comparison to other species (Hays *et al*., 1991; Tucker, 2010) and the use of multiple breeding sites by male loggerheads in the Mediterranean has also been suggested (Casale *et al*., 2013). However, this is the first time that nesting events hundreds of kilometres apart and among multiple geopolitical units have been documented for Mediterranean loggerheads. Our estimate of 12.5% multiple-country nesting could be considered conservative, since all turtles which exhibited this behaviour were tracked from early in the season, suggesting that some of those turtles tracked later may have previously nested elsewhere. These findings challenge the accuracy of published loggerhead clutch frequencies that are based on tag returns at monitored nesting sites, and in turn, current population estimates based on reproductive outputs extrapolated to basin-wide nest counts (Broderick *et al*., 2002; Pfaller *et al*., 2013).These results should also be considered when planning the temporal spread of genetic sampling for haplotype analyses and further tracking studies of nesting females.

Fisheries threats

Of the main countries which host foraging adult loggerheads (current study and reviewed by Luschi & Casale, (2014)), Tunisia stands out as being associated with the greatest number of turtle deaths in fisheries, with at least 5600 deaths per year occurring predominantly in set nets and bottom trawls (see Fig. S2 in Supporting Information; Casale, 2011). The fisheries of Cyprus, Egypt and Libya are each responsible for at least 2700 deaths each, predominantly in set nets, with the exception of Libya where most deaths occur in pelagic longlines and bottom trawls (Casale, 2011; see Table S1 in Supporting Information, see Fig. S2).

The mortalities described in the current study occurred in shallow (Table 1), near-shore waters in populated areas with small-scale/semi industrial fishing fleets (Latakia Harbour, Syria: Rees *et al*., 2010b; Lake Bardawil, Egypt: Nada *et al*., 2013; Kyrenia Harbour, North Cyprus: Snape *et al*., 2013). Such shallow waters are not likely to be used by larger vessels using more industrial methods such as bottom-trawls and in all of these countries the greatest proportion of fisheries deaths occur in set nets (see Fig. S2).

Although the method that we employed to estimate mortality in the current study has been subject to some debate (Chaloupka *et al*., 2004; Hays *et al*., 2004; Bradshaw, 2005), the estimate should be treated conservatively, since the observed death of Turtle AA was not detectable from telemetry and so further deaths may have gone unreported. The survival probability for adults of this rookery may therefore be of a similar magnitude to estimates from other adult loggerhead populations subject to high fishing pressures of 0.81 (Frazer, 1983) and 0.88 (Chaloupka & Limpus, 2002).

Prioritising research

Bycatch mitigation measures are more likely to be supported in small-scale fisheries if their impact on fisher livelihoods is minimised. Meanwhile, such measures should provide protection for large numbers of the most valuable demographic groups, in order to adequately reduce the impact of tolls. Appropriate spatial and temporal limits to any mitigation measure must be set according to detailed information on bycatch rates by specific fishery metiers. The available information both on Mediterranean loggerhead turtle habitat use and on fisheries characteristics are, however, currently insufficient and a three-pronged approach is required to address this.

Firstly, loggerhead turtle tracking studies from sites in eastern Greece, Turkey, Libya and the Levant are required to fill remaining gaps in the literature on post-nesting behaviour of the Mediterranean population. It is important that satellite telemetry studies in these rookeries, as well as in Cyprus, should aim to include male turtles. In a warming world where male numbers may decline because of the temperature dependant sex determination of marine turtle offspring, an understanding of male movements and mortality rates is critical (Hays *et al*., 2014). Secondly, the value of tracking studies could be amplified using predictive habitat models that incorporate remotely sensed environmental data (Jonsen *et al*., 2007; Pikesley *et al*., 2013; Hacohen-Domené *et al*., 2015). In addition, localised empirical studies using aerial surveys (Cardona *et al*., 2005), monitoring coastlines for stranded turtles (Scherer *et al*., 2014), and surveys in fisheries (Carman *et al*., 2011) could further delimit important foraging habitats and their demographics. Thirdly, more detailed small-scale fisheries characterisation studies are required to break down marine turtle bycatch not only by gear type, but with descriptions of individual deployment characteristics, summarising temporal and spatial variability in deployments of specific gear-target catch combinations. Such studies have been undertaken in North Cyprus (Snape *et al.,* 2013) and are urgently needed for trawls and set nets in Tunisia, trawls and demersal longlines in Libya and set nets in Egypt where annual mortalities of marine turtles are thought to be of many thousands (see Table S1, see Fig. S2; Casale, 2011).

However, many of the countries which host loggerhead turtle foraging grounds described here are currently facing political and economic instability which will hinder local research and conservation efforts for the near future. Despite this, by remotely assessing broad habitat use, tracking studies such as ours are a critical first step towards directing such efforts.

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Table 1. Summary of transmitter deployments included in this study. Data from 10 turtles were previously published by Godley *et al*. (2003; turtles C and H) and Broderick *et al*. (2007; turtles A, C, G, H, L, M, O, R, V and X). Turtles C, R and X were tracked from more than one nesting season. For turtles C and X, the first migration track and the foraging site with greatest number of foraging days were plotted in Fig. 2 and 3 respectively. Deployment sites: Alagadi: 35°20'N, 33°29'E; Iskele: 35°16'N, 33°55'E; Akdeniz: 35°20'N, 32°56'E. Estimated depth at foraging sites is the median estimated depth of the filtered Argos locations that were used to generate foraging site kernels (bathymetry data sourced at GEBCO global topographic dataset with one-minute (1') spatial resolution (http://www.gebco.net/)).

Turtle ID	PTT	Manufacturer	Model	Deploy Site	Deploy Date	CCLmin (cm)	Tracking Days	Foraging site EEZ	Foraging Days	Number of Sites Used	For Multiple Sites (Site name:total visits,total days)	Estimated Depth (m) at Foraging Site(s)
A	15414	Telonics	ST6	Alagadi	4-Jul-02	72	404	Cyprus	359	1		7.4
B	118185	Wildlife Computers	SPOT	Iskele	31-May-12	65	352	Cyprus	913	1		53.2
C	29358	Telonics	ST14	Alagadi	11-Jul-01	71	81	Cyprus	58	1		-
C	29050	Telonics	ST18	Alagadi	14-Jun-03	73	1405	Cyprus	1368	1		78.4
D	52813	Sirtrack	K2G	Tatlısu	17-Jun-11	71	1303	Cyprus	1270	2	D1:14,852;D2:13,418	8.6
E	77171	SMRU	SRDL	Alagadi	16-Jul-08	66	708	Cyprus	683	2	E1:3,468;E2:2,215	29.5
F	52816	Sirtrack	K2G	Akdeniz	23-Jun-11	73	393	Syria	370	1		5.5
G	29034	Telonics	ST18	Alagadi	21-Jul-03	77	628	Syria	604	3	G1:1,63;G2:2,296;G3:3,245	17.9
H	29359	Telonics	ST14	Alagadi	13-Jun-01	73	59	Syria	38	1		121.0
I	77172	SMRU	SRDL	Alagadi	2-Jul-09	64	268	Syria	248	2	I1:1,85;I2:1,163	89.3
J	68557	SMRU	SRDL	Alagadi	8-Jun-07	85	260	Lebanon	190	1		8.0
K	52817	Sirtrack	K2G	Iskele	1-Jun-12	74	67	Egypt	27	1		2.1
L	15340	Telonics	ST6	Alagadi	5-Jun-02	71	226	Egypt	195	1		95.0
M	57389	Sirtrack	101	Alagadi	1-Jul-05	76	135	Egypt	80	1		99.9
N	52819	Sirtrack	K2G	Akdeniz	5-Jun-11	73	440	Egypt	367	1		66.7
O	4406	Telonics	ST14	Alagadi	3-Aug-02	69	86	Egypt	71	1		86.4
P	43755	Sirtrack	F4	Iskele	5-Jun-12	68	174	Libya	99	1		72.8
Q	68561	SMRU	SRDL	Alagadi	20-Jun-07	67	166	Libya	102	1		86.2
R	4407	Telonics	ST14	Alagadi	17-Jul-02	73	392	Libya	320	2	R1:2,206;R2:1,114	52.5
R	29049	Telonics	ST18	Alagadi	5-Jun-04	75	70	-	-	-		-
S	52815	Sirtrack	K2G	Iskele	1-Jun-12	75	351	Libya	246	1		96.5
T	53184	SMRU	SRDL	Alagadi	5-Jun-06	65	389	Libya	262	2	T1:3,110;T2:2,152	55.1
U	53182	SMRU	SRDL	Alagadi	21-Jun-06	77	350	Tunisia	257	1		52.6
V	4206	SMRU	SRDL	Alagadi	4-Jul-02	69	139	Tunisia	72	1		19.7
W	118184	Wildlife Computers	SPOT	Iskele	1-Jun-12	80	194	Tunisia	53	1		5.0
X	57384	Sirtrack	101	Alagadi	7-Jun-05	74	176	Tunisia	37	1		-
X	4242	SMRU	SRDL	Alagadi	8-Jul-02	74	422	Tunisia	341	1	X1:2,165;X2:1,176	7.2
Y	34214	SMRU	SRDL	Alagadi	30-Jun-06	78	63	-	-	-		-
Z	57391	Sirtrack	101	Alagadi	24-Jun-05	82	6	-	-	-		-
AA	52815	Sirtrack	K2G	Tatlısu	10-Jun-11	73	34	-	-	-		-

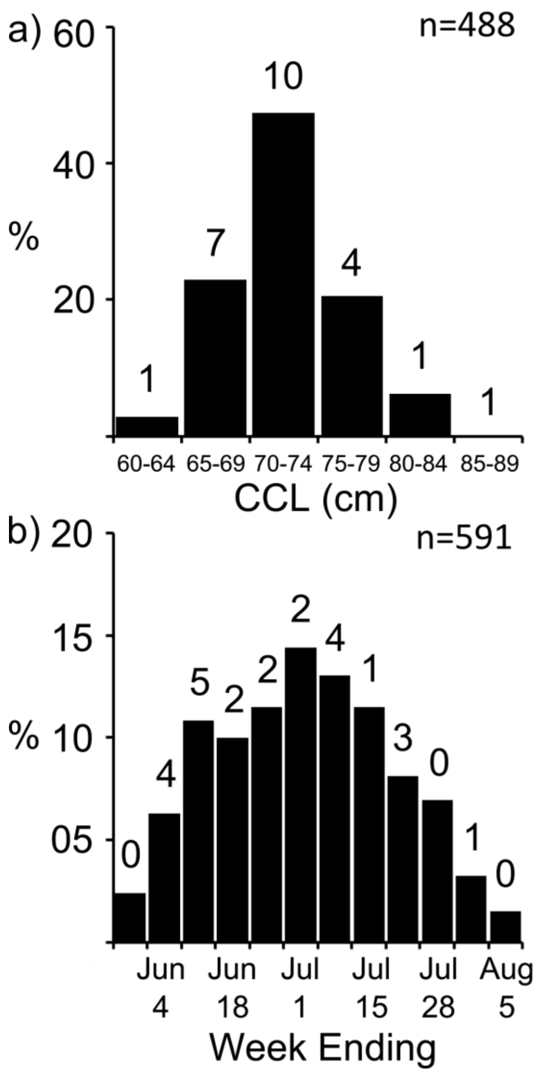

Figure 1. Percentage frequency histograms for (a) size (minimum curved carapace length) and (b) temporal distribution of nesting, of adult female loggerhead turtles on Alagadi study beach, North Cyprus. Numbers above bars represent the number individual nesting females of each bin that were tracked to foraging sites during this study.

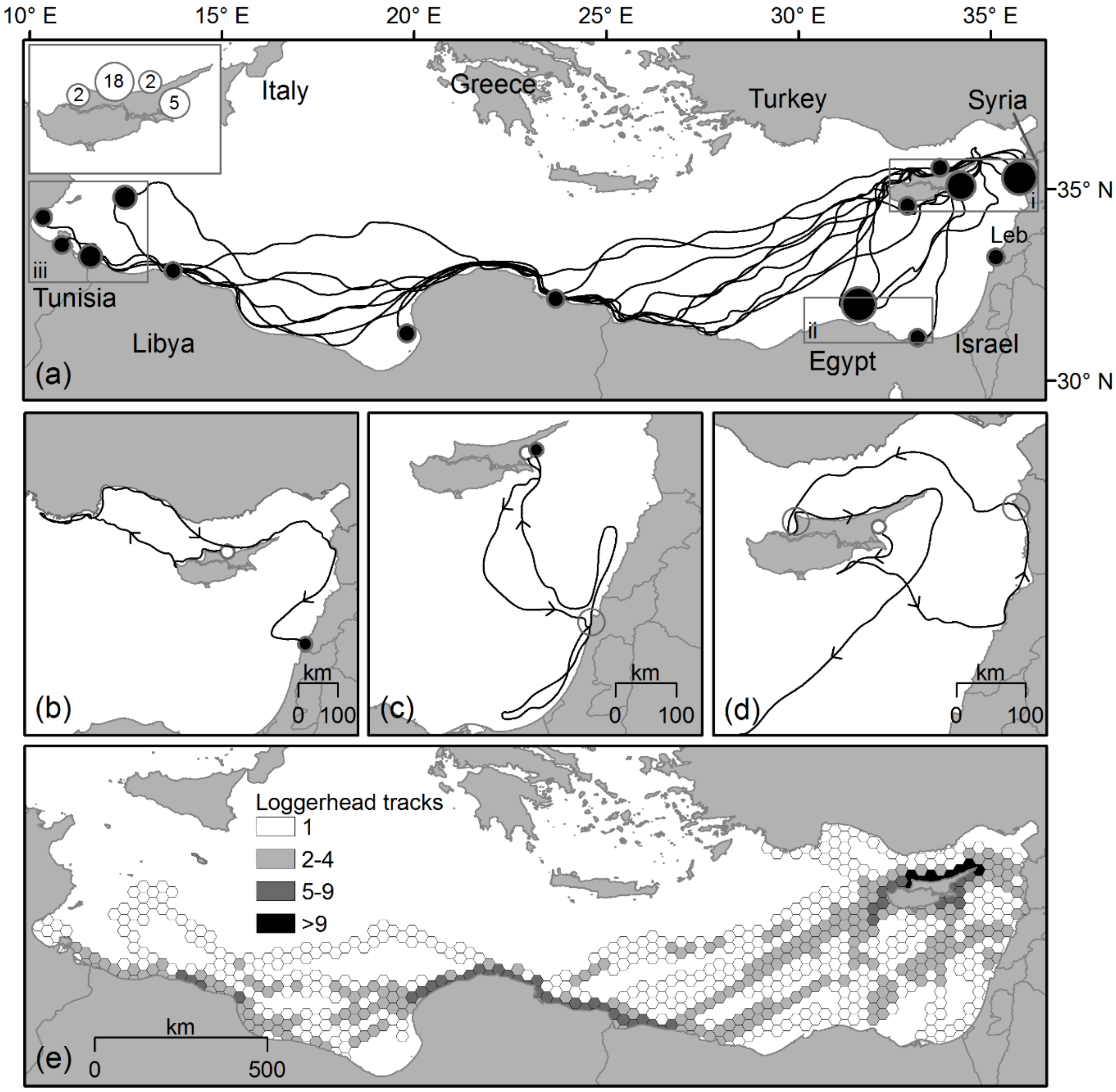

Figure 2. (a) The routes taken by turtles that made post-nesting migrations directly from North Cyprus (see insert box for deployment sites) to foraging sites and distribution of foraging sites. Black circles are scaled to the number of individuals residing in each area (1-4). Boxes i to iii indicate areas mapped in detail in Figure 3. (b) The route taken by turtle J. Open star = sites where onboard sensors detected haul outs. (c) The route taken by turtle B. Open circle = inferred nest site in Israel. (d) The route taken by turtle G. Open circle = inferred nest site in Syria. (e) migratory corridor density map of migrations to foraging sites (n=24).

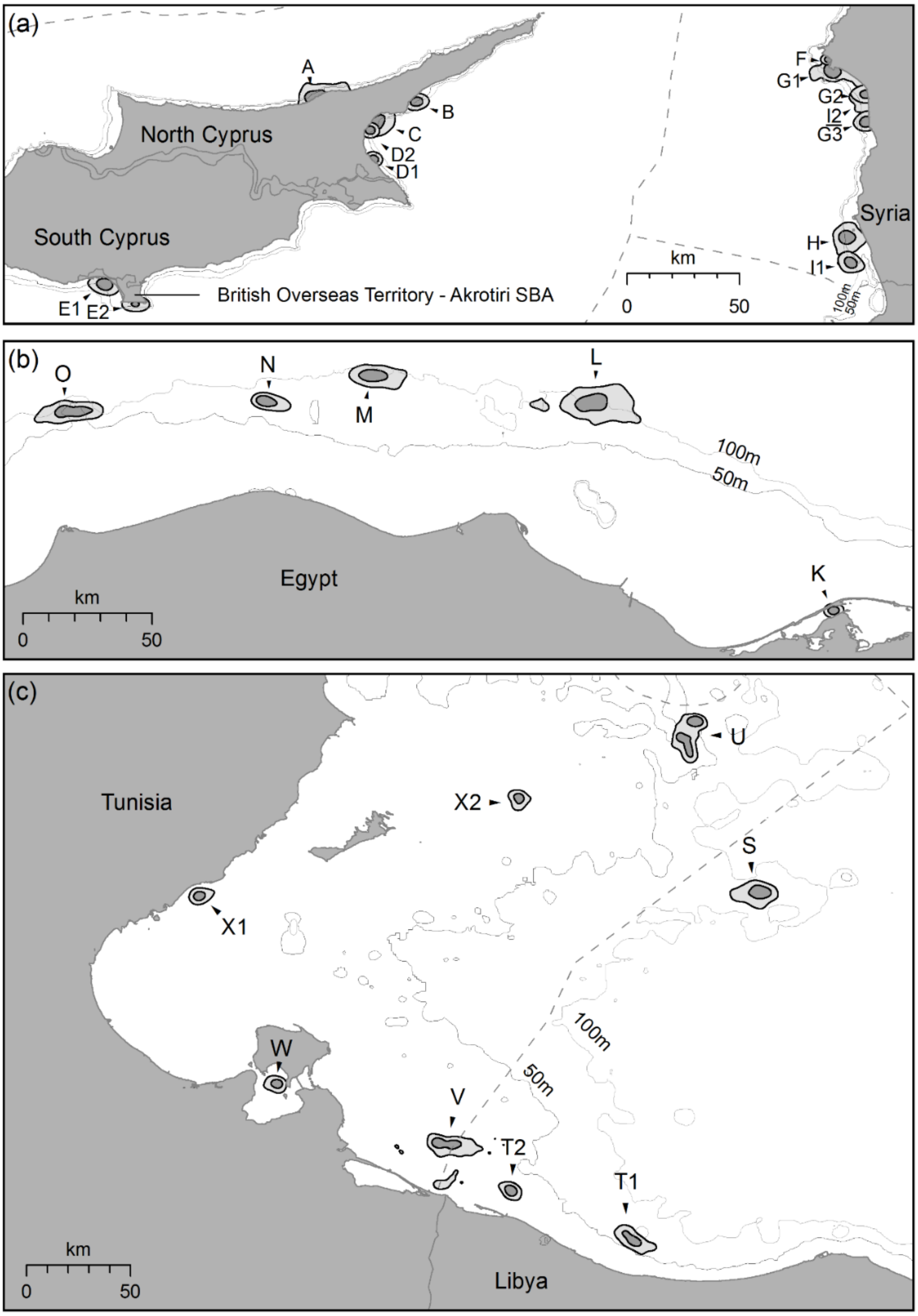

Figure 3. 20% (dark grey) and 50% (light grey) data distribution isopleths produced from kernelled filtered satellite telemetry data for the main foraging sites concentrated in (a) Cyprus and Syria, (b) Egypt and (c) West Libya, the Tunisian coast and shelf. Letters represent individual turtles (Table 1) and their sub-sites where numbered.

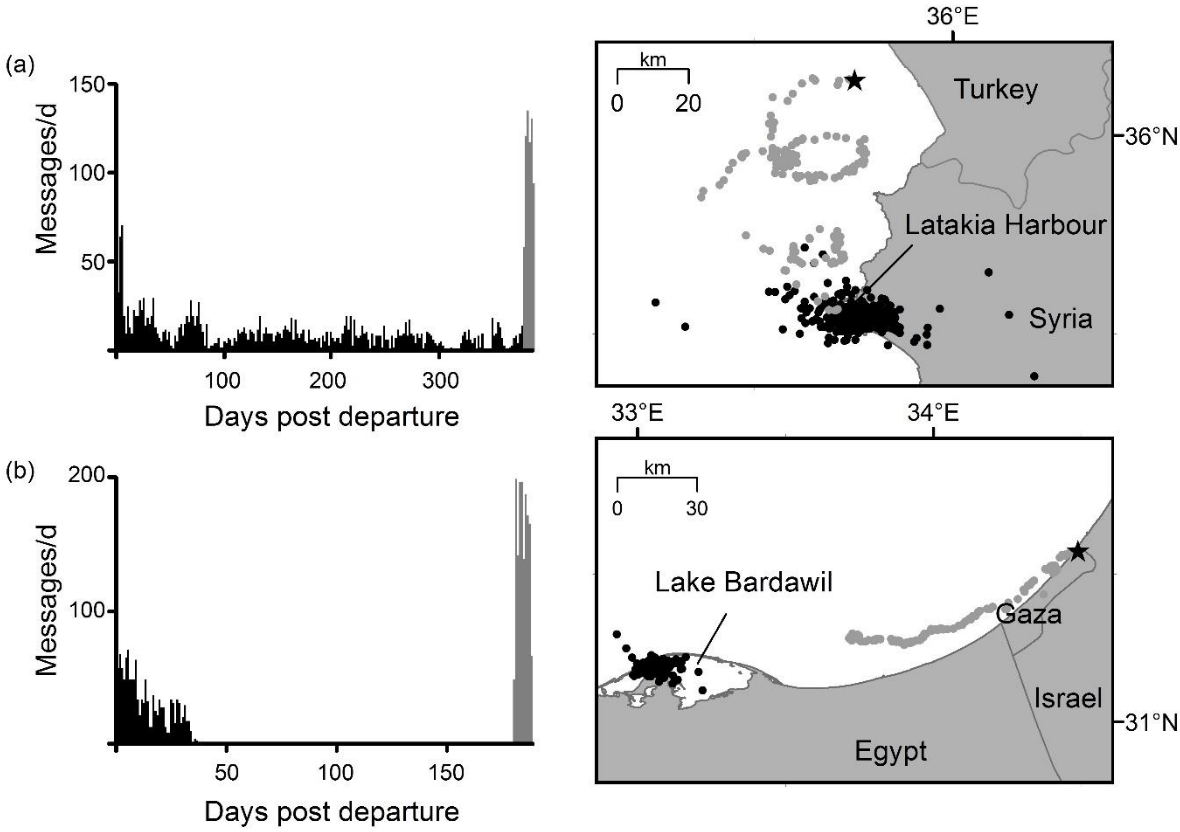

Figure 4. Bar plot showing the number of uplinks received daily by Argos during post-nesting movements (left) and maps showing location data (Location class 0 and Z and speeds >5km h-1 removed) received after turtles reached foraging sites (right) for (a) turtle F and (b) turtle K, both of which likely died. Black stacks = data received before the turtle left its foraging site. Grey stacks = data received after the turtle left its foraging site. These stack colours correspond to black and grey positional data points. Black star denotes the last received location.

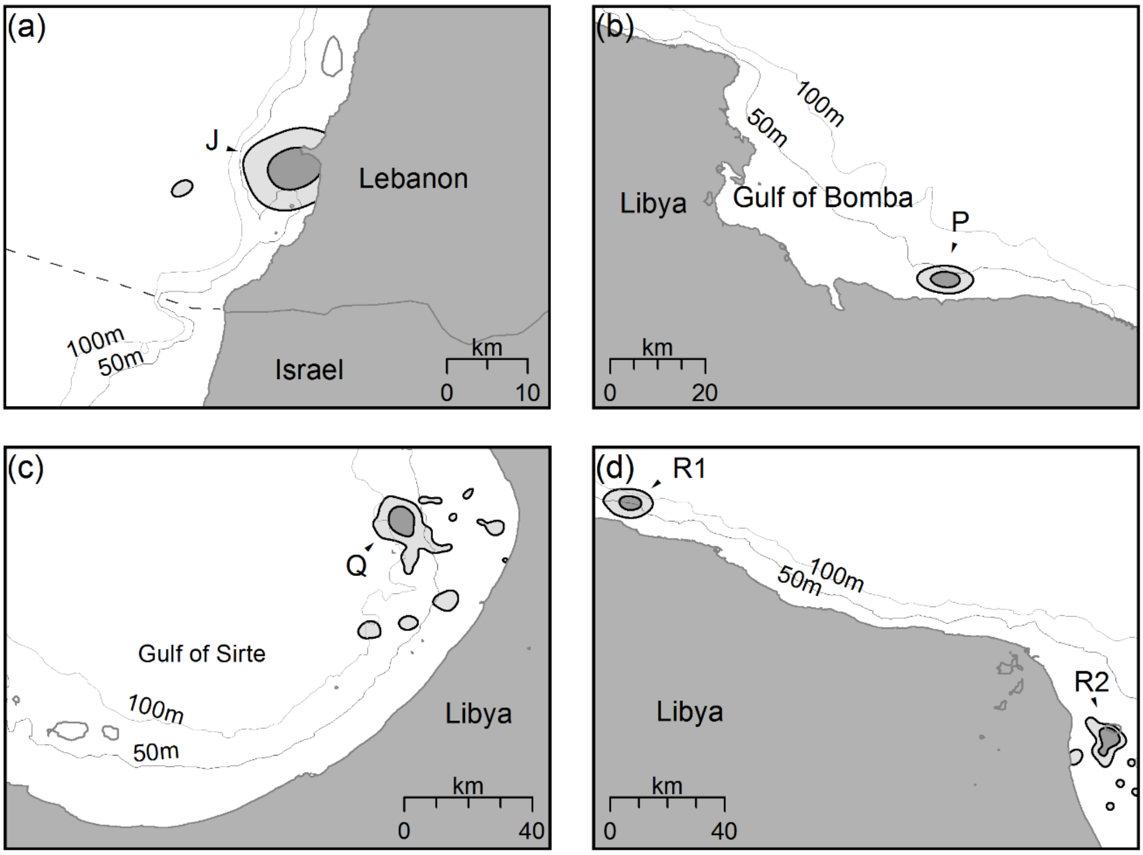

Figure S1. 20% (dark grey) and 50% (light grey) data distribution isopleths produced from kernelled filtered satellite telemetry data for turtles foraging in (a) Lebanon, (b) East Libya (c) Central Libya and (d) Central-West Libya.

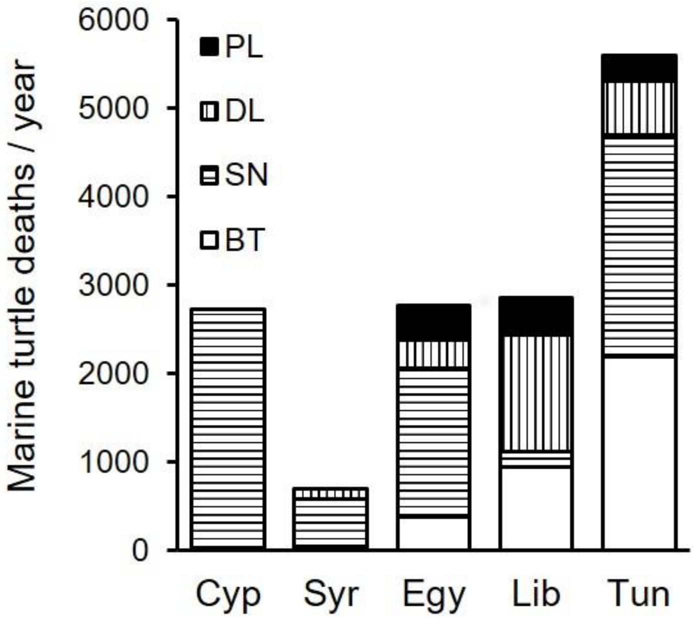

Figure S2. Stacked bar plot of estimated annual marine turtle mortalities by gear types (PL=Pelagic Longline, DL=Demersal Longline, SN=Set Net, BT=Bottom Trawl) for the main countries that host foraging loggerhead turtles tracked after nesting in North Cyprus (Cyp=Cyprus, Syr=Syria, Egy=Egypt, Lib=Libya, Tun=Tunisia). Calculated according to numbers of turtle captures per year and gear type-specific mortality rates compiled and estimated by Casale (2011) and Snape *et al*. (2013).

Table S1. Captures, mortality rate estimates and deaths of marine turtles caught in main fisheries of Cyprus, Syria, Egypt, Libya and Tunisia. Sources: 1= Casale (2011); 2=Snape et al. (2013).

	Bottom Trawl			Set Net			Demersal Longline			Pelagic Longline			Totals		
Country	**Captures**	**MR**	**Deaths**	**Captures**	**MR**	**Deaths**	**Captures**	**MR**	**Deaths**	**Captures**	**MR**	**Deaths**	**Captures**	**Deaths**	**Source**
Cyprus	100	0.2	20	4600	0.6	2760							4700	2780	1,2
Syria	200	0.2	40	900	0.6	540	300	0.4	120				1400	700	1
Egypt	1900	0.2	380	2800	0.6	1680	800	0.4	320	1300	0.3	390	6800	2770	1
Libya	4700	0.2	940	300	0.6	180	3300	0.4	1320	1400	0.3	420	9700	2860	1
Tunisia	10900	0.2	2180	4200	0.6	2520	1500	0.4	600	1000	0.3	300	17600	5600	1
SUM	17800		3560	12800		7680	5900		2360	3700		1110	40200	14710	

Chapter III: Conflict between dolphins and a data-scarce fishery of the European Union

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Abstract

Fisheries depredation by marine mammals is an economic concern worldwide. Questionnaires, acoustic monitoring and participatory experiments are combined here to investigate the occurrence of bottlenose dolphins and the nature of their conflict with set-nets, an economically important metier of Mediterranean fisheries. Dolphins were present in fishing grounds throughout the year and were detected at 28 % of sets. Net damage was on average six times greater where dolphins were present, was correlated with dolphin detections and its associated costs were considerable. An acoustic deterrent pinger was trialled but had no significant effect. More powerful pingers could be trialled. However, establishment of fisheries stock management is urgently advised toward addressing the overexploitation which is likely driving depredation behaviour in a vicious circle between humans and dolphins.

Introduction

Increasing reports of catch depredation among odontocete and pinniped species, reflect the expansion, intensification and diversification of world fisheries and a wide range of marine mammal species depredate in a diversity of fishing gears (Read *et al*. 2006). For example, seals with gillnet sets in northern Europe (Cosgrove *et al*. 2015), killer whales with demersal longlines in the South Atlantic (Guinet *et al*. 2015) and false killer whales with pelagic longlines in the Pacific (Forney *et al*. 2011). Fisheries may face considerable economic losses through spoil of catch and destruction of gear (Brotons *et al*. 2008a; Read, 2008) whilst even low levels of marine mammal mortality through bycatch (accidental or unintended catch: Brotons *et al*. 2008b; Lauriano *et al*. 2009; Read 2008) or injury (Gomerčić *et al*. 2009) associated with depredation, can cause concerning marine mammal population declines (D'Agrosa *et al*. 2000; Lewison *et al.* 2004).

It is important to understand marine mammal depredation interactions, both to provide adequate protection of threatened marine mammal species and to support fishing economies. The latter is particularly relevant in small-scale fisheries (SSF), as they typically support large numbers of fishers (compared to more industrialised fisheries: Jacquet and Pauly 2008, Alfaro-Shigueto *et al*. 2010) and as the economic impact of depredation is shouldered more directly by individuals rather than corporations.

The Mediterranean Sea is a global marine biodiversity hotspot (Bianchi and Morri 2000; Coll *et al*. 2010, 2011). It is also heavily impacted by fisheries, (Costello *et al*. 2010; Micheli *et al*. 2013; Selig *et al*. 2014) with fifty-two percent of stocks overfished, compared to 29% worldwide (Food and Agricultural Organisation of the United Nations [FAO], 2014). Furthermore, studies across six countries that collectively constitute over half of the region's landings (FAO, 2016), indicate that catch estimates are greatly underestimated (Coll *et al*. 2014; Pauly *et al*. 2014; Piroddi *et al*. 2015; Ulman *et al*. 2014, 2015). Polyvalent, small-scale vessels make up 80% of the Mediterranean fleet and these vessels chiefly use set nets such as gillnets and trammel nets (General Fisheries Commission for the Mediterranean [GFCM], 2016) and among these fisheries, little information is available regarding production volumes or bycatch rates (GFCM 2016). With its rich biodiversity and large SSF fleet, the Mediterranean thus provides a great laboratory for examining interactions between SSF and threatened marine fauna.

There is a relative paucity of information regarding the nature and extent of interactions between bottlenose dolphins *Tursiops truncatus* (hereafter referred to as dolphin) and Mediterranean SSF (GFCM 2016), yet, depredation in set nets is reported across the region (Spain: Brotons *et al*. 2008a, 2008b; Gazo *et al*. 2008; France: Rocklin *et al*. 2009; Italy: Bearzi *et al*. 2011, Blasi *et al*. 2015, Buscaino *et al*. 2009, Díaz López, 2006, Lauriano *et al*. 2009, Maccarrone *et al*. 2014, Pennino *et al*. 2015; Croatia: Gomerčić *et al*. 2009; Greece: Gonzalvo *et al*. 2015; Turkish Black Sea coast: Gönener and Özdemir 2012; Turkish Mediterranean coast: Ali Cemal Gücü, personal communication, February 4, 2016; Cyprus: Dawson *et al*. 2013; Libya: Ibrahim Benamer, personal communication, February 4, 2016; Tunisia: Aydi *et al*. 2013). Among these reports, some efforts have been made to assess rates of dolphin depredation and economic damage, but due to variation in parameters measured and in methods employed among studies (for example sighting of dolphins at sets: Brotons *et al*. 2008a, Gazo *et al.* 2008; in fishing areas: Bearzi *et al*. 2011, Blasi *et al*. 2015; net damage: various methods: Brotons *et al*. 2008b, Gazo *et al*. 2008, Rocklin *et al.* 2009; damaged catch: Brotons *et al*. 2008a, Rocklin *et al*. 2009; damaged catch on sighting dolphins: Gazo *et al.* 2008; total landings: Brotons *et al*. 2008a, Buscaino *et al.* 200; catch composition: Rocklin *et al*. 2009), it is often difficult to draw comparisons between fisheries and dolphin populations. In all cases, dolphins are a subject of complaint by fishers as they spoil catch and damage nets. In Spain, Italy and France, studies in commercial fisheries have estimated the annual cost in terms of damage to catch to be €1000-€2000 per vessel or 6.5-8.3% of catch value (Brotons *et al*. 2008b; Gazo *et al*. 2008; Lauriano *et al*. 2004; Rocklin *et al*. 2009). Italian (Bearzi *et al*. 2011) and Greek (Gonzalvo *et al*. 2015) fishers claim that dolphin depredation costs from €500 to €20,000 per vessel annually.

In the Balearic Islands and Sardinia dolphin bycatch in set nets as a result of depredation (Brotons *et al.* 2008) is considered to have serious conservation implications (Bearzi *et al*. 2012; Brotons *et al*. 2008b; Díaz López, 2006). Of stranded dolphins in Croatia, 10% showed laryngeal strangulation resultant from swallowing sections of set net (Gomerčić *et al*. 2009), indicating an additional source of mortality. Given the vulnerable conservation status of the Mediterranean bottlenose dolphin subpopulation (Bearzi *et al*. 2012), the apparent basin-wide geographic extent of the issue and the number of fisher livelihoods affected (of the order of 150,000 polyvalent fishers; GFCM 2016) assessing and mitigating dolphin interaction with set net fisheries should be a priority from both conservation and economic perspectives.

Studies into mitigating dolphin depredation in Mediterranean set net fisheries have focussed on trials of acoustic deterrent devices called 'pingers' as a means of reducing depredation interactions. Pingers emit sounds at frequencies and intensities that are intended to discourage the approach of cetaceans (reviewed by Dawson *et al*. 2013). In these trials, pingers have shown some positive results with 87 % reduction in net damage, 49% reduction in interaction rates and 9 % increase in yield in the Balearic Islands (Brotons *et al*. 2008a; Gazo *et al*. 2008). In Italy net damage was reduced by almost a third with 28 % higher target catch (Buscaino *et al*. 2009; Maccarrone *et al*. 2014). However, acoustic deterrents do not always provide the intended results (Pirotta *et al*. 2016) and in Tunisia, pingers led to increased dolphin depredation (Aydi *et al*. 2013), suggesting that in some cases they may produce a "dinner bell" effect.

Northern Cyprus has a polyvalent fishery which chiefly uses set nets to land fish that is sold in the north of the island and in the Republic of Cyprus controlled south through the green line regulation (EU regulation no: 886/2004: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2004R0866:20080627:EN:PDF). However, despite being a *de jure* area of the European Union, since the north operates as a *de facto* state, the fishery is currently exempt from European Union legislation pending resolution of the Cyprus dispute. During questionnaire surveys to build knowledge of conflicts with threatened marine vertebrates in northern Cyprus (Snape *et al*. 2013), net damage resulting from dolphin depredation was of chief economic concern among fishers. However, since no landings data are available for this region of Cyprus (Ulman *et al*. 2014), it is difficult to contextualise and understand the extent of these interactions based on the opinion of fishers alone. Toward better understanding these interactions and developing mitigation to protect fisher livelihoods we used a questionnaire survey, acoustic monitoring and onboard observations. Our aims were to determine a) the seasonal presence of dolphins in fishing grounds, b) the rate of dolphin interactions with set nets, the chief gear type used by this polyvalent fleet (Ulman *et al.* 2014), c) loss of earnings resulting from dolphin interactions in terms of net damage, contextualised against estimated landings, d) the effect of a pinger on acoustic detections, net damage and landings and e) the rate of any dolphin bycatch and mortality.

Methods

Questionnaire survey

During 2010 and 2011, 140 captains of fishing vessels were surveyed across the ports of northern Cyprus (Fig. 1). The surveys were designed to provide quantitative information on the most important metiers (see Snape *et al.* 2013), temporal interactions between dolphins and set nets, fishing effort, temporal fishing patterns, the frequency of dolphin encounters, depredation events, bycatch and mortality events. Fishers were asked whether they used set nets and to indicate the months during which their nets were most impacted by dolphins. Fishers were asked to indicate on average how many fishing trips they made per month from the options 1-10, 11-20, 21-30, 31-40 and >40. Fishers were asked during which months they were active, whether they had encountered dolphins during the past year, and whether the dolphins had interfered with their fishing during these encounters. They were asked to state the number of dolphins that they generally encounter, whether they had caught any dolphins, if so in which gears and whether those caught had survived.

Monitoring in commercial fisheries

To understand the temporal occurrence of dolphins in coastal fishing grounds and as a reference for comparing rates of dolphin occurrence against those at sets, two CPODs (passive acoustic monitoring instruments that detect toothed cetaceans by identifying the trains of echolocation sounds they produce; chelonia.co.uk) were moored at A) Girne and B) Gemikonağı (Fig.

1) for the period 1 January to 8 August 2014 and 1 January to 31 December 2014, respectively. CPODs A and B were set in waters of 50 m and 40 m depth, respectively. These depths were close to the mean fishing depth recorded during onboard experiments and within fishing areas (Table 1). Both CPODs were attached to mooring lines at 2m above the sea bed. CPODs were deployed and serviced using commercial fishing vessels of participating fishers and were replaced at two to four-month intervals with fully charged and serviced CPODs, thus enabling a continuous dataset. All acoustic data were handled in CPOD.exe (www.chelonia.co.uk) where a classification (KERNO classifier) was used to distinguish dolphin click trains from other underwater sounds. Only those click trains that KERNO identified as high and moderate quality were used for analysis (for validity see Tregenza *et al*. 2016).

To estimate the frequency and extent of dolphin depredation in set net fisheries, 46 experimental sets were carried out onboard 14 commercial fishing vessels (<12m in length), between 15 November 2010 and 17 April 2013. Experimental sets were undertaken from ports across the study region (Fig. 1) and were temporally distributed to reflect the seasonal occurrence of dolphins described by fishermen and according to the fishing season (Fig. 2). In experimental set nets, Aquatec Aquamark® 200 (www.aquatecgroup.com) pingers (wideband frequency modulated waveforms, 200-300 ms long, with harmonic energy in the 5 kHz to 160 kHz band, typically 145 dB re 1 µPa at 1 m) were also tested. To quantify net damage, identical orange multifilament trammel net sections were used, each measuring 1.2 m in height and 80 m in length (total net area: 96 m^2). These trammel nets had an internal mesh size of 18 mm^2 and an external mesh size of 100 mm^2 (Fig. 3). As they are relatively indiscriminate, these nets can be employed for a wide variety of target catch, most typically being used to target red mullet species *Mullus spp*. The nets cost €155 (220 USD) each in 2010.

During each experimental set, two trammel net sections were set at opposite ends of a continuous line of other set gillnet and/or trammel net sets, deployed by participating fishers, measuring hundreds to thousands of meters (Fig. 3, see insert). One of these two 80 m long trammel net sections had a pinger attached to the float line at each end (Fig. 3), the other did not. By setting nets in this semi-independent/paired way with commercial sets, typical commercial fishing conditions were replicated while the impact of any random effects such as depth (nets are set parallel to bathymetric contours), target catch, vessel captain, other depredating animals such as sea turtles, invertebrates etc. were minimised. As the commercial sets involved in our experiments totalled many hundreds of meters in length, the control net was set at sufficiently distant from the pinger net, and greater than the manufacturer's advised spacing of 200 m for these devices. The distance between pinger and control nets was 725 m ± 56 m (mean ± SE). Target catch, depth and placement of the set were at the discretion of the participating fisher, but the experiment was not undertaken when fishing targeted siganids (Rabbitfishes) in shallow water since dolphin depredation was considered by fishers to be less important for those metiers. Target species were striped red mullet (*Mullus surmuletus*; n=25 sets; 54.3%), bogue (*Boops boops*; n=15 sets; 32.6%), Mediterranean parrotfish (*Sparisoma cretense*; n=3 sets, 6.5%) and picarel (*Spicara smaris*; n=3 sets, 6.5%). To limit cumulative damage to the experimental trammel net sections, three identical labelled pairs of nets were used in rotation. Prior to deployment, a coin toss was used to decide which of the two nets of each pair would serve as the experimental unit. This was to reduce biases that might confound results from, for example, a net repeatedly subjected to the same treatment incurring more cumulative damage and, subsequently catching fewer fish and resulting in fewer dolphin interactions. A coin toss was also used to allocate which of the two experimental nets would be deployed first, to avoid biasing treatments due to any resulting modest difference in soak time. Set depths were recorded to the nearest meter at the beginning of each control and pinger net set, from an on-board acoustic fish sounder (Table 1). To estimate the presence of dolphins around sets (Leeney *et al*. 2007), each control and pinger net was set with one CPOD moored at the terminal end, at the bottom of the anchor line, and stationed approximately two meters above the sea bed (Fig. 3). CPOD datasets were gathered from 44 control nets and 45 pinger nets.

Damage to the internal mesh panel of each of the two experiment nets were recorded after every experiment by counting the number of internal mesh units which were removed or damaged. The area of each mesh unit was 324 mm^2 (18 * 18 mm), as such, the extent of damage was quantified as the number of affected mesh units multiplied by the mesh unit area. Once recorded, damage was labelled using adhesive tape, thus allowing the differentiation of damage occurring during preceding experiments from those that occurred during the most recent. On hauling, all fish were removed, identified and weighed individually, except for on one occasion when a large haul of *Spicara smaris* were weighed together to the nearest kilogram to prevent it spoiling, since saleable catch was returned to the fisher.

During trips, other net sets were often made in addition to those involved in our experimental setup. The combined length of all net sets made during a sample of 27 field trips were measured (excluding the two 80m experimental sets) using a handheld GPS.

Wilcoxon matched pairs signed-rank test was used (Wang *et al*. 2010) to compare dolphin presence (dolphin detection positive minutes), net damage (m^2) and catch (g) between pinger and control nets and to compare damage between dolphin present and dolphin absent sets.

Results

Occurrence of dolphins in fishing grounds

Ninety-two percent of fishers (n=131 respondents) reported having observed dolphins in their fishing grounds at some point during the past year. More than 40% of fishers were active throughout the year and dolphins were observed during all months (n=101 respondents; Fig. 2). The proportion of respondents that were active was greatest during spring-autumn peaking in May and the reported temporal pattern of dolphin encounters largely corresponded to their activity (Fig. 2).

Dolphin click trains were detected during all deployment months at CPOD monitoring points A and B (Fig. 4), confirming the year-round occurrence described by fishers. The proportion of dolphin detection positive days per month ranged from 13 to 52 % with 0.3 to 3.2 dolphin detection positive minutes (DPM) per day (mean per month). During each month, frequency of dolphin detection positive days (Fig. 4a and 4c) and mean dolphin detection positive minutes per day (4b and 4d), were higher at CPOD B (except July). Overall, DPM was higher at site B (0.21%) than at site A (0.06%; Fig. 5).

Rate of dolphin interactions

Eighty-six percent (n=87 respondents) of fishers used set nets. Fifty percent of fishers (n=128 respondents) said that on the occasions that they had observed dolphins, that the dolphins had always damaged their nets, 41% said that the dolphins damaged their nets on some of the occasions on which they were observed, and 9% said that the dolphins had not damaged their nets on the occasions on which they were observed.

Bottlenose dolphins were visually confirmed during two experimental sets. Dolphins were detected by CPODS during 12 of the 45 experimental sets in which CPODs were deployed and were visually confirmed on one occasion where CPODs were not used. Dolphins were thus recorded during 13 (28%) of 46 experimental sets. The proportion of DPM was more than tenfold higher at CPODs associated with nets (control and pinger: 1.9%) than at CPODs A and B (0.2%; Fig. 5).

Net damage

Mean net damage per set for all sets of all treatments was 1.4m^2 per 80m set (SE: ± 0.7, range: 0.0-63.1) or a loss of 1.5% of the total net area. However, damage to nets was six times greater where dolphins were recorded (mean ± SE: 3.6m^2 ± 2.4; 3.7% area; Fig. 6) than when they were not recorded (0.6m^2 ± 0.3; 0.6% area). Although these differences were found to be non-significant (P=0.08; Fig. 7), net damage was significantly correlated with the proportion DPMs recorded at CPODs during sets (Spearman's correlation coefficient test statistic: rho=0.26, P=0.02; with outliers removed rho=0.22, P=0.04) suggesting that dolphins were a driver of net damage.

Pinger effect

There was no significant difference in the amount of net damage (P=0.26), DPM (P=0.56) or haul mass (P=0.85) among pinger and control sets (Table 1).

Fishing effort and landings

Of 135 respondents, 19% made 1-11 trips, 50% made 11-20 trips, 10% made 21-30 trips and the rest made over 30 trips per month. The experimental nets caught 98.1 kg of fish during the 46 experiments. Mean haul mass was 1.1 kg per 80 m set (SE: ± 0.18; range: 0-10 kg). Fifty-seven species were caught, the majority not saleable locally and in small amounts. Of 21 species where the total catch from all sets exceeded 500 g (See supplementary figure Fig. S1), 10 species made up the saleable catch which were 78% of the total catch mass, the remaining 22% were used for bait, subsistence or were discarded.

The mean combined length of nets set by fishers per observed trip (n=27) was 2004 m (SE: ± 148, range: 781-4150). By extrapolation using the mean observed haul per 80 m set and the mean combined set length, it is estimated that on average 26.7 kg of fish are caught in set nets per fishing trip. For fishers making 132-240 trips per year (most fishers make 11-20 trips per month; see above), annual catch in set nets is therefore of the order of 3.5-6.4 t/year. Assuming 215-300 active vessels (estimated by Snape *et al*. 2013), the total catch of the northern Cyprus set net fishery is therefore of the order of 759-1923 t/year (215 vessels landing 3.5 t/year to 300 vessels landing 6.4 t/year).

Group sizes and bycatch

Group sizes of two to three were estimated on each of the two occasions when onboard observers sighted dolphins and, on both occasions, they were identified as bottlenose dolphin (*Tursiops truncatus*). These estimates support those of fishers who reported seeing groups of 1-5 dolphins (62%), with others seeing groups of 6-10 (24%) and >10 (14%; n=114 respondents). Two fishers (1.7%; n=118 respondents) had caught one dolphin during the preceding year, both dolphins were dead on hauling. Extrapolating this result to the number of fishing vessels that were active during the study (215-300 estimated for the study area by Snape *et al*. 2013), an indicative annual dolphin mortality level is likely to be less than 10 per year. No dolphin bycatch was recorded during onboard observation.

Discussion

The use of CPODs to record dolphin occurrence over dime during monitored set net sets is novel and has potential for standardising cetacean-fisheries interaction studies to allow more meaningful comparisons among fisheries, regions and dolphin populations. Such techniques are increasingly being used for the detection of a range of cetacean species (Baumann-Pickering *et al*. 2015; Miller *et al*. 2015; Hardy *et al*. 2012). Estimates of depredation rates vary across the Mediterranean. During the current study, dolphins were recorded at 28 % of sets, greater than a 12.4% rate of depredation reported in Corsica (Rocklin *et al*. 2009), less than a 38% rate of depredation off Sicily (Buscaino *et al*. 2009) and the 68.7% rate reported in Sardinia (Díaz López, 2006). Although the relatively low number of experimental sets limited the statistical power of our analysis, the occurrence of dolphins was far greater at set nets than at control sites, there was greater damage to sets at which dolphins were recorded and a positive correlation between acoustic detections and net damage. The latter is a useful result in that for further studies, CPOD data may possibly be used as a yardstick to measure economic losses during sets, without the necessity to laboriously mark and count damage incurred.

What's the cost?

Net damage resulting from dolphin depredation can certainly be very costly to fishers. During one set when dolphins were present (42% DPM for the set duration and visually confirmed during hauling), an experimental net lost 79% of its area and was beyond repair. To quantify the true costs of net damage, a more detailed study of the economics of set-net fishing is required, because the mechanisms used by fishers to address net damage are not known. However, our study provides evidence to support claims of Mediterranean fishers that they are expending thousands of Euros annually replacing nets. The mean set-net length of 2004m costs >€3000 (80m sections during the current study cost €155 and were competitively sourced). At the observed mean damage rate of 1.5% area per set, most fishers, who we estimate to be making 132-240 sets per year, may need to address their net damages many times annually if, hypothetically, they replace their nets once 50% area damage is reached. Compounding these costs, fishers increase their set lengths over time, to maintain catch rates against decreasing fish stocks (Ulman *et al*. 2014). Additionally, loss of earnings due to spoiled catch through depredation, although of secondary importance to the fishers we interviewed, likely also constitutes significant loss of earnings (Lauriano *et al.* 2009). Fish landing prices across Mediterranean countries of the European Union are relatively high (EC, 2002) and in Cyprus are the highest (data for southern Cyprus; GFCM 2016) and dolphin depredation may be of influence here; such are the cumulative costs of landing fish.

Dolphin population insights

The passive acoustic monitoring results presented here for reference sites show that dolphins are present off the coast of Cyprus throughout the year. In Atlantic and Pacific waters, passive acoustic monitoring also found year-round presence of bottlenose dolphins (Simon *et al*. 2010; Elliot *et al*. 2011). These studies however used arrays of TPODs (precursor of the CPOD) and detected seasonal and spatial patterns in dolphin behaviour. Longer-term studies using CPOD arrays would be useful in assessing the habitat use of dolphins using the coast of Cyprus (Kiszka *et al*. 2012), to examine in more detail their seasonal interaction with fisheries (Blasi *et al*. 2015) and to estimate more accurately the true threat level from fisheries and other sources (Hashimoto *et al*. 2015; Huang *et al*. 2014; Parsons *et al*. 2015).

Our indicative dolphin mortality estimate of <10 individuals per year, demonstrates that bycatch is an occasional occurrence in northern Cyprus. This could be considered conservative, since fishers may withhold information regarding mortality of protected species. Appreciable quantities of net were removed from our study nets by dolphins and laryngeal strangulation (Gomerčić *et al*. 2009) or gastro-intestinal complications associated with consuming net pieces, could be a secondary source of mortality. Given the small group sizes reported, such losses are a cause for concern (Brotons *et al.* 2008b). To understand the threat level in a population context, more extensive onboard observations are required to fully assess the bycatch rate, whilst boat-based cetacean surveys, aerial survey, telemetry studies and strand monitoring, would be useful in assessing dolphin density, seasonal movements and population connectivity (Mullin *et al.* 2017, Byrd and Hohn 2017).

Pervasive fishing increasingly driving dolphin depredation

Whilst investigating the conflict between Mediterranean SSF and bottlenose dolphins, this study also provides a useful insight into the nature and intensity of a fishery for which very little data exist. As a *de facto* state, no fisheries landing statistics for northern Cyprus are recorded by the Food and Agricultural Organisation of the United Nations. This is the subject of a recent study (Ulman *et al*. 2014) which estimated that the most active 11% of fishers, were landing just 2.7 t/year in 2013 and that the majority landed <0.2 t/year. The results of the current study suggest that the majority of fishers may land 3.53 t annually in set nets alone. Mean annual landings for Cyprus of 1749 t (years 2010-2013) reported by the General Fisheries Commission for the Mediterranean (GFCM 2016) are likely to be underestimated by at least 40 %, given the minimum catch estimate for northern Cyprus set net fisheries estimated here. It is therefore important to incorporate first-hand on-board observations into catch estimates. Although little catch goes to waste, the sustainability of this fish extraction must be considered as the ecosystem impacts of continuous removal of fish are acute and are considered a driver of dolphin depredation (Read, 2008; Rocklin *et al*. 2009).

Over-fishing in the Mediterranean Sea has become so pervasive that it has created a vicious cycle for the dolphins and fishers as they compete for the remaining fish. The depleted fish stocks result in extremely low catches, requiring more net and a situation where depredation can result in significant economic losses because any loss is significant. The depleted prey for the dolphins appears to fuel the depredation problem and perhaps explains why the acoustic pingers, which are designed to repel dolphins, have instead attracted them in some cases. Given the dolphin depredation reported here, the intensity of sound emitted by our acoustic sounding pinger (max 145dB) may have been insufficient to act as deterrent.

Future management implications

Higher acoustic intensity pingers, termed mid-range or acoustic harassment devices by Dawson *et al*. (2013), could be tested and user-programmable deterrents are available. However, if high intensities are found to be more successful, the impact of introducing high intensity anthropogenic noise into coastal fishing grounds must also be properly considered, to avoid unintended consequences (Parsons *et al*. 2015). Aside from the impact of excluding dolphins from foraging areas, there may be adverse impacts on other species (Estabrook *et al*. 2016; Hatch *et al*. 2016; McKenna *et al* 2016), particularly cetaceans, although published data regarding this group are scarce in the region (Reeves and Notarbartolo Di Sciara 2006).

A more holistic managerial approach should be urgently developed not only to provide dividends for northern Cyprus's coastal ecosystems, but for fishers too, as sustainably managed stocks support more profitable fisheries (Hilborn 2012, Quetglas *et al,* 2016, Vendeville *et al*. 2016). Currently, fishing using set nets in northern Cyprus is unlimited to licenced fishers, with no restricted zones, periods, size selectivity or landing quotas, no assessment or monitoring of stocks. Fishers from across northern Cyprus have called for sustainable management and cite lack of government capacity to develop and regulate restrictions. Such governance problems are common among small-scale fisheries, where bottom-up management of stocks are increasingly being employed, with benefits including increased and stabilised landings, landing prices and improved catch per unit effort (Beger *et* al. 2004, Gelcich *et* al. 2009, Defeo *et al.* 2016). Northern Cyprus could serve as an arena in which to test management models in which sustainable systems are managed by fishers (Tilman *et al*. 2017) and once established, these systems may result in reduced dolphin interactions, since overexploitation drives depredation. Given that the revised Common Fisheries Policy aims to ensure that all commercial fish stocks are managed at their maximum sustainable yield by 2020 (Chato Osio *et al*. 2015), the European Union could be called upon with priority to build capacity in fisheries management and governance, for example through its aid programme for the Turkish Cypriot Community (EU regulation No. 389/2006: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006R0389&from=EN)

Acknowledgements

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Table 1. Descriptive statistics for soak times and set depths of control and pinger-equipped nets. DPM = Dolphin detection positive minutes, SE = Standard error.

		Depth (m)	Soak duration (mins)	CPOD minutes	DPM	% DPM	Net damage (m^2)	Total haul (kg)
Control	**Total**		10360	9997	169		27.11	44.4
	Mean	43	225	227	3.8	2.2	0.60	0.97
	SE	3	17	17	2.2	1.4	0.25	0.24
	Range	17-155	36-588	35-589	0-91	0.0-61.1	0.00-10.17	0-10
Pinger-equipped	**Total**		9275	8987	188		101.64	53.7
	Mean	42	202	200	4.2	1.3	2.26	1.17
	SE	4	16	17	3.3	0.9	1.42	0.27
	Range	16-150	57-592	53-592	0-152	0.0-42.7	0.00-63.12	0-10

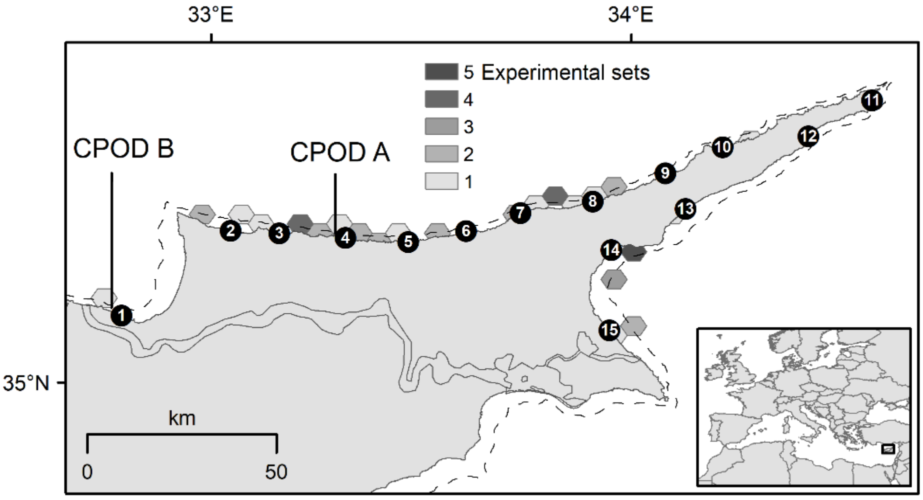


Figure 1. Map of study area. Distribution of experimental sets represented by shaded hexagons (size = 5km between parallel edges) where tone indicates the number of experiments (n=46) undertaken within in each (see insert key). Black numbered circles indicate fishing harbours. Fishing vessels participating in the study were based at harbours 1, 3, 4, 6, 7, 8, 10, 13, 14 and 15. Arrows indicate the position of static CPODs A and B. Grey broken line indicates the 100m bathymetric contour. Harbour locations are 1: Gemikonağı, 2: Kayalar, 3: Lapta, 4: Girne, 5: Alagadi, 6: Esentepe, 7: Tatlısu, 8: Kaplıca, 9: Balalan, 10: Yeni Erenköy, 11: Zafer Burnu, 12: Şelonez, 13: Kumyalı, 14: İskele and 15: Mağusa.

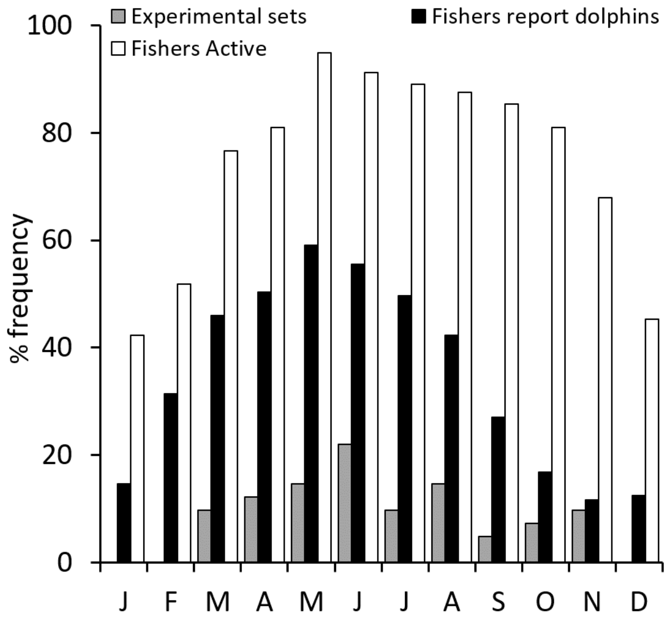


Figure 2. Temporal distribution of experiments (n=46) made during the study period, opinion of fishers regarding months during which dolphin interactions are most frequently encountered (n=101 respondents) and months that fishers claim to be active (n=124 respondents).

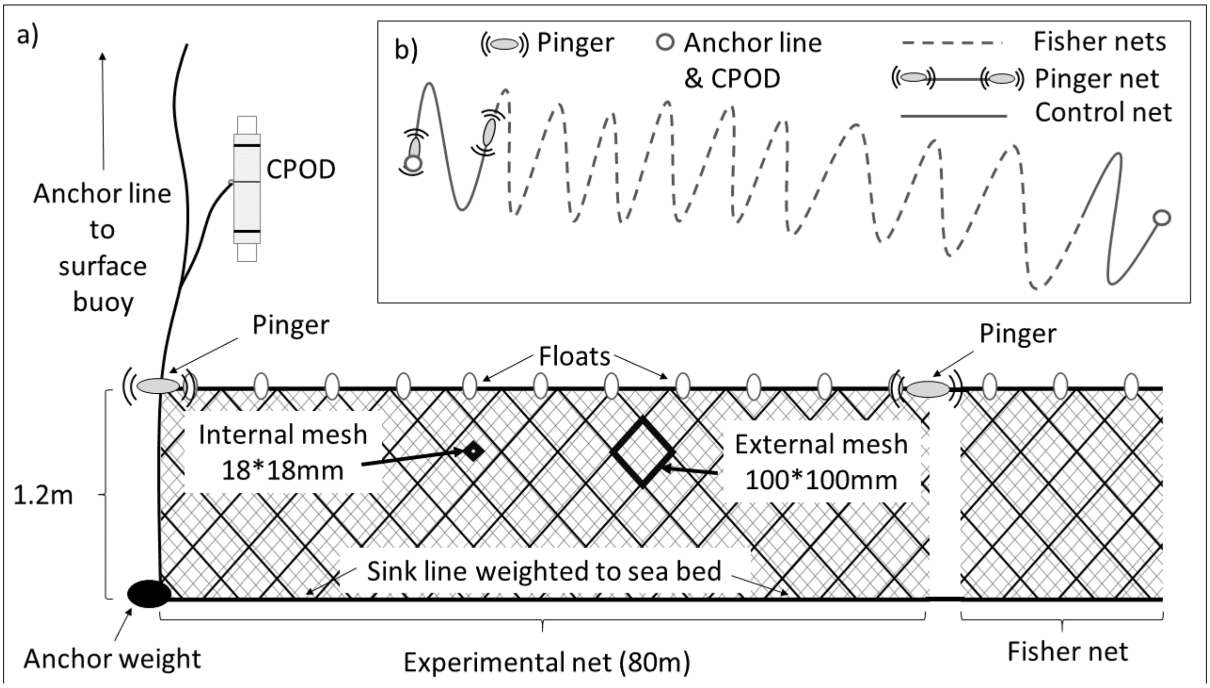


Figure 3. Schematic representation of experimental set net configuration. a) The vertical configuration of pinger sets. Control set configurations were identical except without pingers. Experimental and control sets were deployed at terminal ends of a larger set of commercial nets deployed by the fisher (see Methods). b) Typical horizontal placement of nets in relation to each other and to fisher net set. Objects are not drawn to scale.

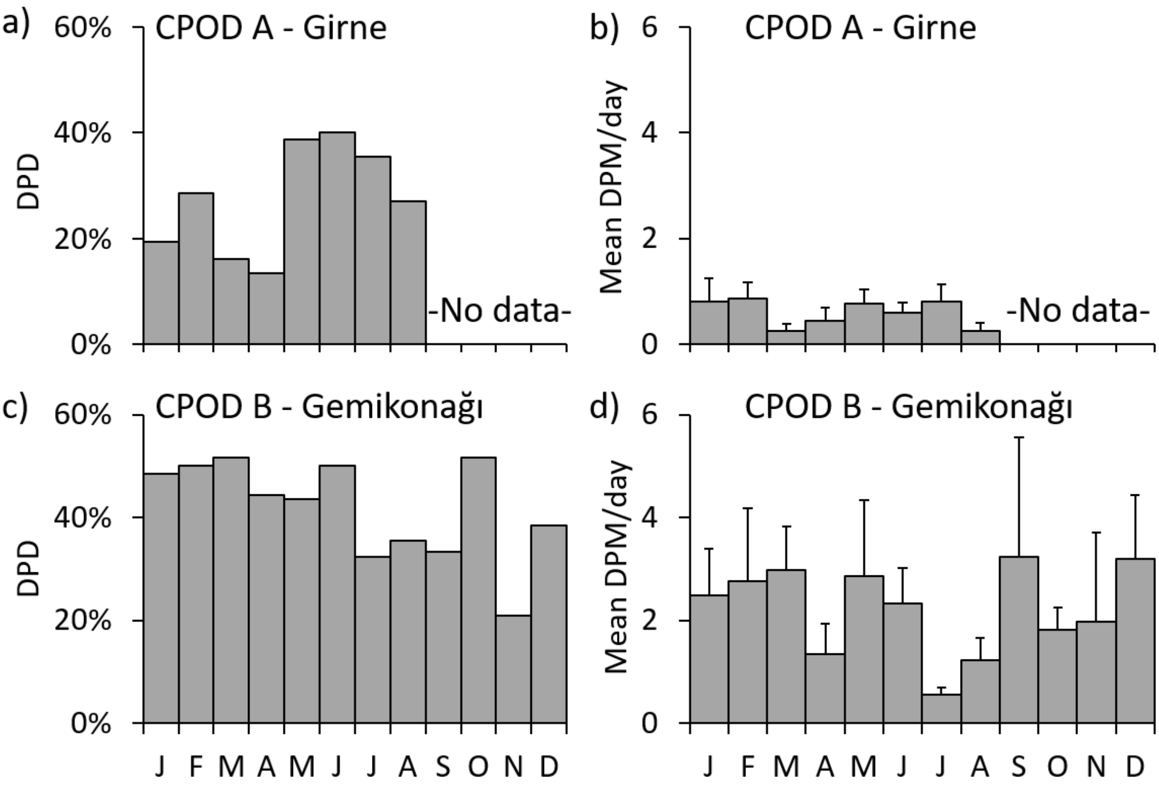


Figure 4. Summarised dolphin detections (Quality: Hi and Mod) at acoustic monitoring points by month during 2014. Proportion of dolphin detection positive days (DPD) in each month at a) CPOD A and c) CPOD B. Mean (with SE bars) proportion of detection positive minutes (DPM) per day by month at b) CPOD A and d) CPOD B. See Fig.1 for locations of CPODs A and B. CPODs were not set at site A during September to December.

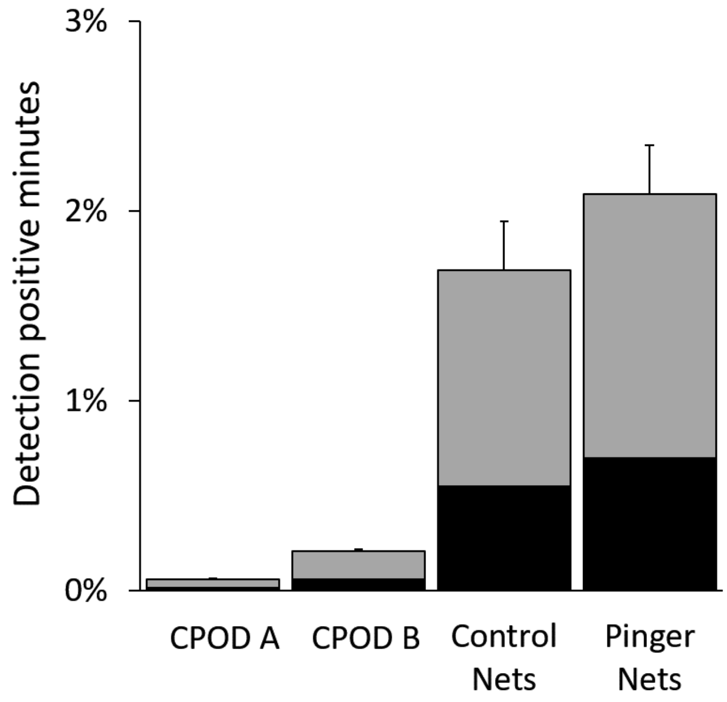


Figure 5. Proportion of dolphin detection positive minutes (DPM± 95% CI) recorded at CPODs A, B, and CPODs at control and pinger net sets. Black and grey shading indicate high and moderate (respectively) quality assigned by KERNO classifier.

Figure 6. Experimental net damaged during a set at which dolphins were detected by CPODs.

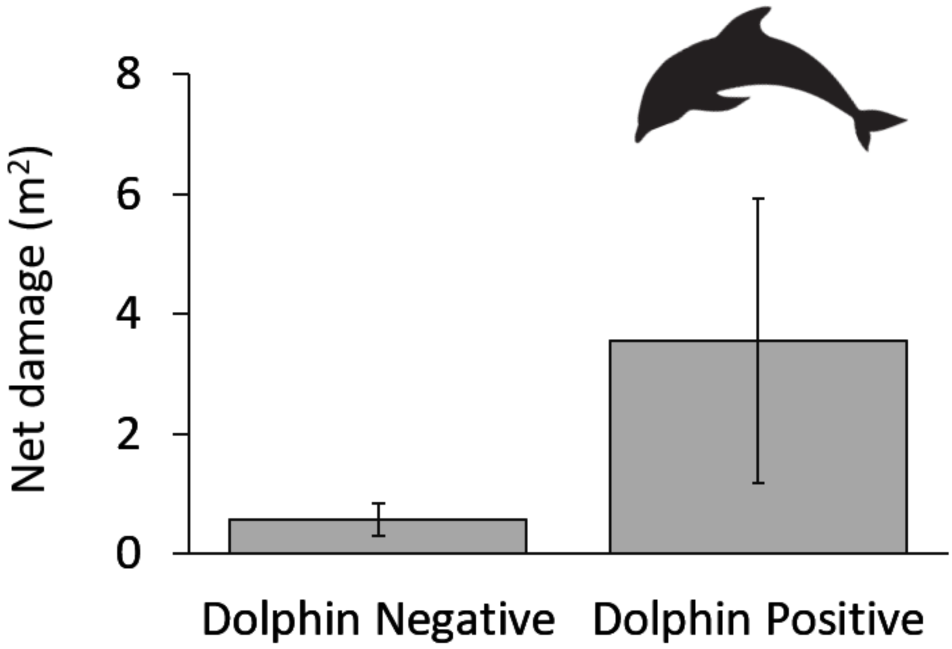
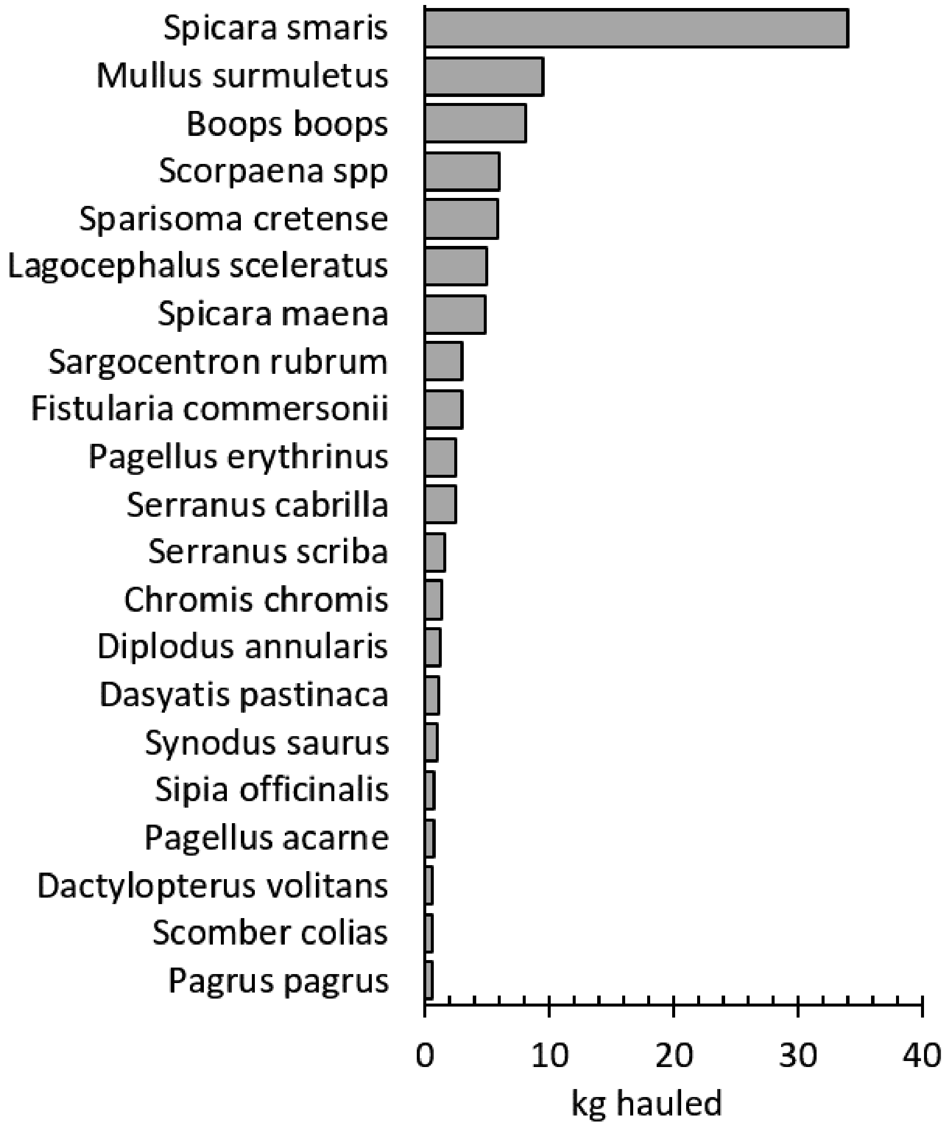


Figure 7. Damage to set nets (mean ± SE bars) for dolphin negative (no dolphins recorded at sets; 0.57m^2 ± 0.27) and dolphin positive (dolphins recorded at sets; 3.55m^2 ± 2.37) sets. Wilcoxon signed-rank test result: P=0.08.



Supplementary figure S1. Total haul mass (kg) across the 92 experimental sets of 80m trammel nets. Only species for which total haul mass exceeded 0.5kg are shown.

Chapter IV: Off-the-shelf GPS technology to inform Marine Protected Areas for marine turtles.

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Abstract

The financial expense of tracking solutions often impedes effective characterisation of habitat use in threatened marine megavertebrates. Yet some of these taxa predictably aggregate at coastal breeding sites, providing conservation opportunities. Toward a low-cost solution for tracking marine megavertebrates, we trial conventional GPS data loggers against Argos satellite transmitters for assessing inter-nesting habitat use of marine turtles. Devices were attached to green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles nesting at a study site in Cyprus, where patrol teams were in place to retrieve GPS loggers from turtles returning to lay subsequent clutches. GPS tracking revealed loggerhead turtles to predominantly use areas outside the boundaries of an MPA proposed for the region, while both species under-used much of the MPA area. Due to high location error, Argos data were considered unsuitable for such fine-scale assessments (all location classes except Z were included in our analysis). However, Argos tracking showed half the loggerhead turtles sampled also nested outside of the patrolled study area, demonstrating connectivity with other proposed MPAs. This was not accounted for by GPS tracking, because females exhibiting this behaviour rarely returned to the study beach, precluding GPS retrieval, thus, demonstrating the power of remote data access. The low-cost GPS technology could be considered in similar cases, where recapture is likely and where funding barriers preclude the use of Argos-relay fast-acquisition GPS technology. In combining the accuracy GPS and the continuity of Argos, the latter provides the best solution in most scenarios, but at far greater cost.

Introduction

Marine megavertebrates typically disperse over large spatial scales, across which anthropogenic threats are diverse, difficult to assess and therefore challenging to mitigate (Block et al., 2001; Croxall et al., 2005; Maxwell et al., 2013; Scales et al., 2014). As conservation becomes increasingly important to human development, animal tracking studies have become key in establishing priority areas at sea for addressing loss of biodiversity (Anadón et al., 2011; Coll et al., 2012; Ramos et al., 2017). To meet the demand of growing research and need, biologging solutions for marine megavertebrates have evolved to encompass a broad range of species, scenarios and biological questions (reviewed by Crossin et al., 2014 and Hays et al., 2014a).

Prior to the inception of Argos-based satellite tracking in the 1980s, marine megavertebrate habitat use studies were reliant on mark-recapture methods (Godley et al., 2008). Under many circumstances recapture of study animals is highly improbable, and their movements may be broad, unpredictable and remote with great effort and extended durations needed (eg. Horrocks et al., 2016). Animal tracking in the marine realm has therefore become heavily reliant on the Argos satellite system for real time global location estimation and data retrieval (Gredzens et al., 2014; Martínez-Miranzo et al., 2016; Reynolds et al., 2017; Thums et al., 2017). The cost of taxon-bespoke Argos platform transmitter terminals (PTTs) along with the associated Argos system fees is typically $2000-6000 USD per study animal, depending on the type of unit used and the duration of tracking. This has meant that understanding the habitat requirements of many populations of conservation concern has been fiscally unachievable (Jeffers and Godley, 2016). In some cases, protected areas could have been more effective, had tracking data been incorporated in their design (Witt et al., 2008; Hays et al., 2014b., Mazor et al., 2016).

Whilst their broad dispersal poses a management challenge, many marine megavertebrate taxa aggregate to breed/nest/rear young at predictable locations and during set seasons, often in human-populated coastal areas, where the diversity and magnitude of anthropogenic threats can be elevated (Barlow et al., 2002; Castillo-Géniz et al., 1998; Haynes, 1987). At breeding sites, human effects (such as direct harvesting, habitat degradation) are acute because reproductive individuals and/or the process of reproduction are impacted. Conversely, breeding aggregations present a valuable opportunity for conservation. If priority coastal areas can be identified and human activities within these areas managed, then reproduction can be safeguarded and, indeed, some populations have shown significant and sustained recovery after cessation of decades or centuries of human pressures at breeding sites (Staniland et al., 2011; Weber et al., 2014).

Aggregation at breeding sites may provide an opportunity for data loggers to be deployed and subsequently retrieved, negating the requirement for remote data links. For example, onboard data loggers have been used to study incubating seabirds (Scheffer et al., 2012), whelping seals (Jeanniard-du-Dot et al., 2017) and nesting marine turtles (Houghton et al., 2002). Such taxa show fidelity to terrestrial breeding sites which they visit repeatedly within seasons, allowing adequate recapture rates for biologging studies. The reduction in size of low-cost (approximately $75 USD), off-the-shelf GPS loggers, developed for the more competitive human tracking market, has increased the financial feasibility of animal tracking (e.g. when modified to track birds: Bodey et al., 2014). Such units require extended surface time to acquire satellite ephemerides and almanac data, so for diving marine megavertebrates that surface only briefly to breath, tags use fast-acquisition GPS logging technology such as FastLoc® (eg. Hoskins et al., 2015). But such tags are relatively expensive due to technology copyrighting and the cost of calibrating and individually testing tags for specific taxa (eg $3300 USD pers comm Kevin Lay, Wildlife Computers). Even at discrete breeding sites where probabilities of recapture are relatively high, a proportion of tags will be lost, as not all animals will be recaptured. Given the expense of fast-acquisition GPS tag losses, an Argos-relay to upload archived GPS data is thus advisable, again at significant additional cost per study animal (eg $5000 USD pers comm Kevin lay, Wildlife Computers), plus monthly Argos payments.

Among diving marine megavertebrate taxa, marine turtles are an appropriate group for tracking studies using archival data loggers, because they migrate from dispersed foraging grounds to aggregate off discrete beaches, onto which females emerge predictably to lay multiple nests. During mating and inter-nesting periods (the period between subsequent nesting events), marine turtles usually spend many weeks or months within habitats proximal to their nest sites, where Marine Protected Areas (MPAs) can be established to mitigate threats such as fisheries bycatch (Casale et al., 2017; Casale and Heppell 2016), industrial activities such as seismic surveys (Nelms et al., 2016) or dredging (Whittock et al., 2017), limited or prolonged pollution events (Lauritsen et al., 2017; Wallace et al., 2017), boat strikes (Denkinger et al., 2013), human exploitation (Stringell et al., 2015) and human disturbance (Schofield et al., 2010; Zbinden et al., 2007). Many of these are prevalent in the Mediterranean (Casale et al 2018).

To delimit priority marine turtle habitat-use zones, telemetry is often the most efficacious method. Where habitat use is being studied at such fine scales as during inter-nesting movements, GPS-quality location estimates have been advised (Thomson et al., 2017, Witt et al., 2010), but, due to the short surfacing periods of marine turtles, these have to date required Argos-relay fast-acquisition GPS devices (Schofield et al., 2007, 2009a; Shimada et al., 2017., Thomson et al., 2017). Considerable funding barriers (tens to hundreds of thousands of dollars per site) therefore exist to establishing well managed MPAs off the thousands of protected nesting beaches identified and monitored around the world (Hamann et al., 2010).

At a monitored nesting site in the northern Cyprus, where nearly all nesting turtles are encountered by an established field team (Stokes et al., 2014), we set out to trial and compare the utility of conventional GPS loggers and Argos-only satellite telemetry (PTTs), in assessing the inter-nesting habitat use of sympatric green (*Chelonia mydas*) and loggerhead turtles (*Caretta caretta*). Using marine turtles as a case example for diving marine megavertebrates, our goals were to determine whether Argos-linked fast-acquisition GPS technology was necessary, or whether either Argos PTTs or conventional GPS loggers could be used at lower cost.

Methods

Study Area

In northern Cyprus, nesting of green turtles and loggerhead turtles is sympatric; some nesting beaches are used more intensively by one species than the other, but both species use all monitored beaches at least occasionally. Intensive night-time monitoring and tagging has been undertaken at Alagadi Beach (Fig. 1) since 1993. These two bays of 1.2 and 0.8 km in length, form part of a locally designated Specially Protected Area and boundaries have been delineated for a proposed Natura 2000 site (European Union network of protected areas; Fuller et al., 2009a). The Natura 2000 site management plan includes an MPA, within which fisheries and other human pressures are to be regulated to protect marine turtles while they are aggregating off the nesting beaches (Fig. 1). To prevent disturbance of nesting females the Department for Environmental Protection enforce closure of the Alagadi beaches between 20:00 and 08:00 and the Society for the Protection of Turtles (SPOT) in partnership with the Marine Turtle Research Group at University of Exeter, are permitted to undertake studies. An international team of volunteers are hosted by SPOT near Alagadi beaches and beach patrols are made at 10 minute intervals throughout each night to ensure that all nesting females of both species are identified, monitored and tagged (Broderick et al., 2002; Stokes et al., 2014). The mean annual number of green and loggerhead turtles nesting at the study site are 74 and 35 females respectively (2013 to 2017).

Deployment method and location data handling – Argos PTT

Twenty-six female green turtles and 18 female loggerhead turtles were tracked after nesting at Alagadi between 1998 and 2015 (for post-nesting analysis see Stokes et al., 2015; Snape et al., 2016, Bradshaw et al., 2017). Argos PTTs ((Platform Terminal Transmitters) for details see online Appendix Table A1) were attached using epoxy resin according to the method described by Godley *et al*. (2002). Of the tracked females 17 green turtles and 11 loggerhead turtles laid subsequent clutches prior to their post-nesting departures and hence provided inter-nesting datasets. These sample sizes represent 23% and 31% (respectively) of the mean annual nesting population of green and loggerhead turtles recorded at Alagadi.

For each nesting female, data were included until the turtle's final clutch and subsequent departure from beaches in northern Cyprus. Where movement from a previous location would have required swimming speeds of >5km.h^{-1} (a commonly used expected threshold for marine turtles; Witt et al., 2010; Hart et al., 2013) these data were removed. Locations were then filtered according to the location class (LC) error estimates assigned by Argos (LC 3: <250 m; LC 2: 250-500 m; LC 1: 500-1500 m; LC 0: > 1500 m; LC B: unknown; LC A; unknown; CLS 2008), although, when compared to simultaneously recorded Argos-relay fast-acquisition GPS locations from tracked marine megavertebrates, these Argos LC errors have differed considerably (Witt et al., 2010). LC Z (invalid; CLS 2008) were removed. To examine any differences between habitat use during day and night periods, whilst also limiting the effect of auto-correlation on habitat utilisation mapping, data were allocated into 12-hour tracking periods and further processed to one location per 12-hour period (Day: 07:01-19:00; Night: 19:01-07:00). Within these periods, where available, a single location (with descending preference LC 3,2,1,A, B, 0) was used. If two or more locations of the same preferred LC remained within a given 12-hour period, the median location was used (Revuelta et al., 2015).

Deployment method and location data handling - GPS

Based on the success of their use with seabirds (eg. Wakefield et al., 2013., Soanes et al., 2016; Bodey et al., 2014., Froy et al., 2015) iGotU GT600 (Mobile Technology; GPS locations generated within minimum 35 seconds from cold start) GPS trackers were used to track 16 female green turtles and 26 female loggerhead turtles during inter-nesting intervals at Alagadi in 2013 and 2014. Various user-definable data acquisition schedules and two housing methods were used and to conserve battery life, devices were programmed to undergo periods of inactivity (see online Appendix Table A2). Following a method similar to Walcott et al (2012), plastic platforms were fastened to turtle carapaces using epoxy resin to enable mounting and removal of housed GPS trackers, which were fastened with cable ties (for detailed method see online appendix Table A2). Twenty-nine deployments were made on green turtles and 36 deployments were made on loggerhead turtles using 50 GPS trackers, resulting in 20 inter-nesting data sets for 13 green turtles and 15 inter-nesting data sets for 13 loggerhead turtles (see online appendix Table A3 for details of failed deployments). These sample sizes represent 18 % and 38 % (respectively) of the mean annual nesting population of green and loggerhead turtles recorded at Alagadi.

Nesting emergence was assumed where >1 terrestrial location was logged in succession at a beach, indicating an extended haul out. Such data were removed and separated from the at-sea location data, for which one location per 12-hour period was retained (section 2.2).

Nesting emergences outside of the monitored study beach

Some of the females tracked by PTT stayed within the coastal waters of Cyprus, to lay further clutches on beaches other than Alagadi. The approximate nest site was visually assigned to the nearest potential nesting beach by monitoring the number of messages received from transmitters (Rees et al., 2010; Tucker, 2010; Stringell et al., 2015) whilst using inter-nesting interval duration as a guide to expected clutch deposition (for green and loggerhead turtles nesting at Alagadi, respectively, mean = 12.5 days, SD = 1.65 and 13.4 days, SD = 1.62; Broderick et al., 2002). Any turtles tracked by GPS that subsequently nested at remote beaches, were not recaptured at Alagadi, thus such data were lost. However, some animals tracked by GPS emerged to nest, without success, at other beaches, prior to returning to nest successfully at Alagadi, and the locations of these nesting attempts were mapped using the resulting emergence data (section 2.3).

Habitat utilisation mapping

A single coordinate, the midpoint of the Alagadi nest site, was used to estimate displacement of tracked turtles according to the processed Argos and GPS data. Data were pooled by species and by tracking method. The Kernel Density tool (ArcGIS 10.2.2) was used to determine habitat utilisation distributions (UDs; 25%, 50% and 75%) to view and compare the spatial extent of turtle habitat use. We used the default search radius setting for this package which computes the bandwidth parameter specifically for each input dataset, using Silverman's Rule of Thumb (Sheather, 2004). Habitat utilisation distributions and filtered locations were mapped alongside the proposed Alagadi Natura 2000 (European Union network of protected areas; Fuller et al., 2009a) site marine boundaries, to assess the degree of protection afforded to each species in their respective marine zones, and to compare inter-specific habitat use and the utility of the two tracking methods.

Results

Tracking data availability

Turtles tracked by Argos PTT

The 17 green turtles were tracked by PTT for 378 days across an estimated 31 inter-nesting intervals, yielding 1760 locations, from which 628 locations (one in each 12-hr turtle tracking period for which data were available) were derived for analysis (see online appendix Table A4). Most of these 12-hr locations were derived from LC's A and B (A-B: 86.9%; 3: 3.0%; 2: 5.3%; 1:4.6%; 0: 0.2%). Across turtles, the majority of 12-hr turtle tracking periods provided one or more locations (mean: 82%, ±SD: 18; range: 36-100%) and the frequency of data-available 12 hr tracking periods was relatively consistent during inter-nesting intervals (Fig. 2a).

The 11 loggerhead turtles were tracked by PTT for 319 days across an estimated 25 inter-nesting intervals, yielding 493 locations, from which 308 locations (one in each 12-hr tracking period for which data were available) were derived for analysis (see online appendix Table A4). Most of these 12-hr locations were derived from locations of LC A and B (A-B: 79.3%; 3: 4.9%; 2: 7.4%; 1:4.9%; 0: 3.6%). Compared to green turtles, fewer 12-hr tracking periods provided one or more location (39%; ± 25, 7-72%). The frequency of data-available 12-hr tracking periods was relatively consistent during inter-nesting intervals with fewer 12-hour tracking periods providing data than for green turtles (Fig. 2b).

Turtles tracked by GPS

The 13 green turtles were tracked by GPS for 254 tracking days across 20 inter-nesting intervals, yielding 844 locations from which 120 12-hr tracking locations were used in analysis (see online appendix Table A4). Across deployments, data were available for approximately one quarter of 12-hr tracking periods (27% ± 20; range: 9-77%). The frequency of data-available 12-hr tracking periods was skewed, with fewer locations toward the end of inter-nesting intervals (Fig. 2c).

The 13 loggerhead turtles were tracked by GPS for 217 tracking days across 15 inter-nesting intervals, yielding 504 locations from which 97 12-hr tracking locations were used in analysis (see online appendix Table A4). Across deployments, location data were available for 21% of 12-hr tracking periods (±SD: 19; range: 6-77%). The frequency of data-positive 12-hr tracking periods was relatively skewed, with fewer locations toward the end of inter-nesting intervals (Fig. 2d).

Nesting emergences outside the Alagadi study beaches

Of the turtles tracked by PTT, three (18%) green turtles laid one clutch (Fig. 3a and c) and six (56%) loggerhead turtles laid 1-3 subsequent clutches (Fig. 3b and d) away from Alagadi. Only one of these females, a loggerhead, returned to nest at Alagadi after nesting elsewhere. Of the recaptured turtles tracked by GPS, one green turtle made a nesting attempt at another sandy beach (Fig. 3g), and five loggerhead turtle females made nesting attempts across a 20 km area of coastline surrounding Alagadi (Fig. 3h) prior to returning to nest and recapture at Alagadi.

Marine habitat use

When assessed by PTT (Fig 3a and b), 25%, 50% and 75% habitat UDs were at least an order of magnitude greater for both species than when using GPS (Fig. 3e and f; Table 1). UDs were relatively more inflated for green turtles than for loggerhead turtles. The PTT derived 25% habitat UD (Fig. 3c and d) almost encompasses the entire GPS derived dataset for green and loggerhead turtles, except for outlying locations (Fig 3.e and f).

Despite these differences, some species-specific inter-nesting habitat use patterns were common among tracking methods. Green turtles tended to remain in the close vicinity of the nesting beach while loggerhead turtles made both local and wide-ranging coastal movements. Loggerhead turtles were therefore shown to occupy markedly broader habitat UDs (Table 1, Fig.3) and displaced further (Fig.4) than green turtles, using both methods. However, because PTTs provided data for three green turtles using subsequent nest sites, not shown by GPS, UDs were spread across a markedly broader coastal area (Fig. 3a). In contrast, UDs of green turtles tracked by GPS were almost entirely restricted to the close vicinity of the nesting beach (Fig 3e, g and i), with very low displacement values (Fig 4). Meanwhile, loggerhead turtles tracked by PTT moved over a wider area than green turtles (Fig.3b), across which over half were considered to be nesting. This habitat connectivity was better demonstrated by PTT, with two of other proposed MPAs being used by loggerhead turtles and one by green turtles (Fig. 3a-b). One other MPA was used by loggerhead turtles tracked by GPS, Fig. 3f). Broad loggerhead turtle habitat use and displacement was also indicated by loggerhead GPS tracking, although no nesting events were detected outside Alagadi by this method (Fig.3, Fig 4).

The median displacement of green turtles tracked by PTT and GPS respectively was 2.3 km (inter-quartile range (IQR): 1.0-7.0, range: 0.1-89.9) and 0.6 km (IQR: 0.4-0.8, range: 0.1-5.2; Fig. 4). The median displacement of loggerhead turtles tracked by PTT and GPS respectively was 14.3 km (IQR: 4.7-30.9, range: 0.2-97.8) and 2.6 (IQR: 1.1-9.4, range: 0.0-56.9; Fig.4).

Around the Alagadi nesting beaches, most GPS locations occurred within the 30 m bathymetric contour. Green turtles utilised habitats generally shallower than 10 m, with an apparent diel movement from Alagadi's western embayment into deeper waters between 10 and 30 m by day (Fig. 3g and i). Loggerhead turtles remained largely within the 10 to 30 m bathymetric contours. Eighty-nine percent of GPS derived locations for green turtles were within the proposed Alagadi marine Natura 2000 area, while only 30% of loggerhead locations were within this area. Because of the low location accuracy of Argos data, no inferences can be made to the bathymetric bands occupied or fine-scale movements of either species when tracked by PTT.

Discussion

The study of two marine turtle species at the same location has afforded insights regarding the utility of conventional GPS logger to gather short-term marine megavertebrate habitat use data, at reduced cost compared to Argos or Argos-relay fast-acquisition GPS tracking. While clearly being relevant to the study of inter-nesting movement of marine turtles, similar techniques could be applied to the foraging excursions of colonially breeding penguins and pinnipeds. Even at low volumes, the high accuracy GPS data were of greater value in home range analysis than Argos data, as to account for autocorrelation, data are filtered to one location per unit time (typically per 24hr period) (Griffin et al., 2013; Hart et al., 2013; Revuelta et al., 2015; Thomson et al., 2017; Witt et al., 2010). With modifications (see section 4.4), this low-cost equipment could become much more relevant in the realm of marine megavertebrate tracking.

Habitat use

General patterns of habitat use were common among the two tracking methods with green turtles remaining relatively close to the nesting beach and loggerhead turtles using a broader area and dispersing to distant coastal areas (both methods), where over half were shown to be nesting (PTT), including within other Natura 2000 areas. Loggerheads regularly emerged onto beaches near to Alagadi (GPS) presumably to investigate nesting opportunities. This low nest site fidelity was particularly highlighted when three loggerhead turtles tracked by PTT early in the nesting season subsequently nested in three other countries (Snape et al., 2016). Conversely, due to their high nest site fidelity, green turtle rookeries on Cyprus exhibit significant genetic stock structuring (Bradshaw et al., 2018), which is supported by both tracking methods.

Conventional GPS tracking showed that green turtles remained close (almost entirely within 1km) to the nesting beach, generally using waters <10 m deep, supporting previous dive logging studies of Hays et al. (2002) and Fuller et al. (2009b) at this site. The latter study observed diel habitat use of green turtles, with turtles using greater depths during the day, which again supports the findings of our conventional GPS tracking. These diel patterns may be attributed to human disturbance, as the near-shore areas vacated during daylight hours, correspond to those most heavily used by bathers (lead author personal observations). Diurnal patterns could also be tied to natural behaviour such as thermal niche selection (Schofield et al., 2009b), or foraging behaviour, with turtles moving out to forage on sea grass beds during the day (Christiansen et al., 2017; Gredzens et al., 2014; Fuller et al 2009b). Loggerhead turtles used deeper waters, between the 10 and 30 m bathymetric contours, with few GPS locations occurring in waters >50 m deep and this supports the results of a dive study by Houghton et al. (2002) at Alagadi, which found two breeding loggerhead turtles to be using waters of <20 m. Argos satellite tracking (PTT) failed to provide such spatial detail but did show that some green turtle females used broader areas when visiting other nest sites on Cyprus, a feature of their behaviour which GPS tracking missed.

Critical appraisal of methods

Although the current study does not examine the accuracy of the GPS devices used, the difference in home range size resulting from GPS and Argos data was of the same order reported by Thomson et al (2017), who compared FastLoc® Argos-relay fast-acquisition GPS data and Argos data, suggesting a GPS accuracy comparable to FastLoc® when used in this way. Thomson et al (2017) also compared FastLoc® GPS and Argos tracking data when only high-quality Argos locations are retained (LC:1, 2 and 3). During that analysis, home ranges sizes were found to approach those derived from GPS data, but due to low data volumes, even over extended tracking durations, habitat UDs poorly defined spatial use. During the current study, high-quality Argos locations were few per individual or absent which is typical of Argos tracking studies with marine turtles (Witt et al., 2010). Retaining only these both reduced our sample size and resulted in insufficient data volumes. The accuracy of the available Argos data was therefore deemed not high enough to undertake detailed home range analysis.

Due to their great costs, sample sizes for marine turtle habitat use studies are usually fiscally dependent and although more tracks are always preferable (Godley et al., 2008, Jeffers and Godley 2016), small numbers of tracks are valuable to conservation plans (Mazor et al., 2016). We therefore consider our tracking sample sizes (13 individuals of each species; 18 - 38 % of females nesting annually), appropriate for advising management to protect nesting turtles according to core habitat UDs. Provided that similarly representative sample sizes can be attained, the conventional GPS devices are useful for the description of inter-nesting habitat use and to define localised MPAs for the protection of turtles aggregating off important nesting beaches. However, the trackers are less likely to detect habitat use at and around other subsequently visited nest sites. As we found with PTT tracking of similar numbers of individuals, this is because nesting attempts outside the Alagadi study site were usually followed by post-nesting migration without the opportunity for recapture. The strength of PTT tracking here is its utility in determining habitat connectivity, metapopulation structure, in estimating overall fecundity and population estimates based on nest counts, where nesting attempts can be identified (Tucker, 2010; Weber et al., 2013).

Conservation recommendations

In 2009 and 2010 through the European Union's aid programme for the Turkish Cypriot Community (EU regulation No. 389/2006: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006R0389&from=EN), five potential Natura 2000 sites were identified for coastal areas of northern Cyprus (Fuller et al., 2009a, 2009c, 2009d, 2010a, 2010b). The sites were selected according to the presence of important terrestrial biotypes, marine turtle nesting beaches, Mediterranean monk seal (*Monachus monachus*) haul out sites and seabird colonies (Audouins gull (*Larus audouinii*) and Mediterranean shag (*Gulosus aristotelis desmarestii*)). MPAs were allocated to 1.5 km offshore, to also protect seagrass beds (*Posidonia oceanica*), which are ubiquitous around the island (Bianchi et al., 1999). The proposed MPA management plans include no information on the habitat use of the marine megavertebrates they aim to protect, nor on any fisheries activities. Yet they advise that fishing using set nets, which are the mainstay of the small-scale fishing industry (Snape et al., 2018a) should not be permitted in these broad areas. The five proposed MPAs cover over a quarter of the northern Cyprus coastline. Despite the perceived cost of tracking marine megavertebrates, biologging studies may have paid dividends in this case, because the current management plans require extensive fisheries bans, potentially affecting the livelihoods of hundreds of fishers and requiring huge annual budgets to police fisheries closures across large areas. The value of marine megavertebrate habitat use studies should therefore be fully considered prior to designing such management plans, with appropriate analysis of available tracking technologies according to the long-term economic impacts of potential management decisions (Mazor et al., 2016; McGowan et al., 2017).

In the current study, a major area of core loggerhead UD fell eastward of the proposed Alagadi MPA and large areas were not used intensively by turtles. We propose that to protect the nesting turtles, the eastern boundary should be extended eastward by 1.7 km (to longitude 33.523°) to encompass this important loggerhead area, increasing the coverage of filtered turtle locations from 89% to 97% for green turtles and from 30% to 50% for loggerhead turtles. Meanwhile zoning in western areas of the MPA could permit human activities as appropriate where there are few aggregating turtles. Further inter-nesting habitat use studies are required to similarly address inter-nesting habitat use and connectivity among the four other MPAs.

Given its low cost, if there are suitable questions to be answered using conventional GPS technology alone, they can clearly be investigated with greater power for much less financial outlay, other than the labour involved in retrieving the units, which in this case, was already in place. Conventional GPS could provide a useful tool with which established local marine turtle conservation stakeholder groups could directly drive tracking studies, thus, tackling a communication gap between academic practitioners who traditionally drive such research and marine managers (Jeffers and Godley 2016). However, in combining large GPS data volumes and remote data access, fast-acquisition GPS is the best solution in scenarios where large fiscal resources are available.

Recommendations for further tracking

The observed temporal skewing of GPS data was attributed to battery failure of some devices during the inter-nesting period and this short longevity is a major limitation. However, technical modifications could be used to overcome this. A conductivity switch could be integrated so that power-consuming satellite searches are only made during periods at the surface, and for large study animals (eg. for all adult marine turtles), a larger battery size could be afforded. With a custom-built housing and a more appropriately placed antenna, more data could be acquired per unit time. The problem of study animals not returning to the precise study beach or colony for data recovery, may be overcome by integration of a UHF (Ultra High Frequency) and/or GSM Global System for Mobile connection) link, to transmit GPS data packages to a base station at the breeding site or via GSM networks respectively; such devices are used with solar cells for tracking large flighted birds (Ponchon et al., 2017) and have been used with success for tracking loggerhead turtles (Schofield et al., 2013). These data upload methods may incur lower monetary costs than the Argos satellite relay typically used to upload datasets logged onboard in marine turtle tracking.

Given the increased longevity of Argos devices and improvements in attachment methods, we recommend that Argos PTTs are deployed at or as close to the first clutch as possible, to maximise the value of satellite tracking programmes. Thus, additionally allowing provision of more accurate information on life history traits such as nest site fidelity and clutch frequency (Rees et al., 2012; Snape et al., 2016; Tucker, 2010), both critical parameters of population ecology and a global research priority for marine turtles (Rees et al 2016).

Conclusion

Argos tracking, is clearly of great relevance in tracking animals over larger spatial scales, addressing habitat connectivity and identifying migration routes, but has limited value for assessing habitat use of species using relatively small areas such as in coastal MPAs. By providing both high resolution data and information on habitat connectivity, Argos-relay fast-acquisition GPS tags provide the best overall solution in most tracking scenarios where sufficient funds are available. Where funding barriers exist, the fact that conventional GPS devices can provide high-quality at-sea data for marine turtles is useful and shows their utility for informing MPA planning, where diving marine megavertebrates can be reliably recaptured after periods of weeks at sea.

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Table 1. Area (km^2) of habitat utilisation distributions for green and loggerhead turtles assessed by PTT and GPS.

	Green turtles		Loggerhead turtles	
Habitat UD	PTT	GPS	PTT	GPS
25%	4.5	0.1	117.1	4.0
50%	18.2	0.4	370.1	12.8
75%	90.3	0.9	1081.6	47.0

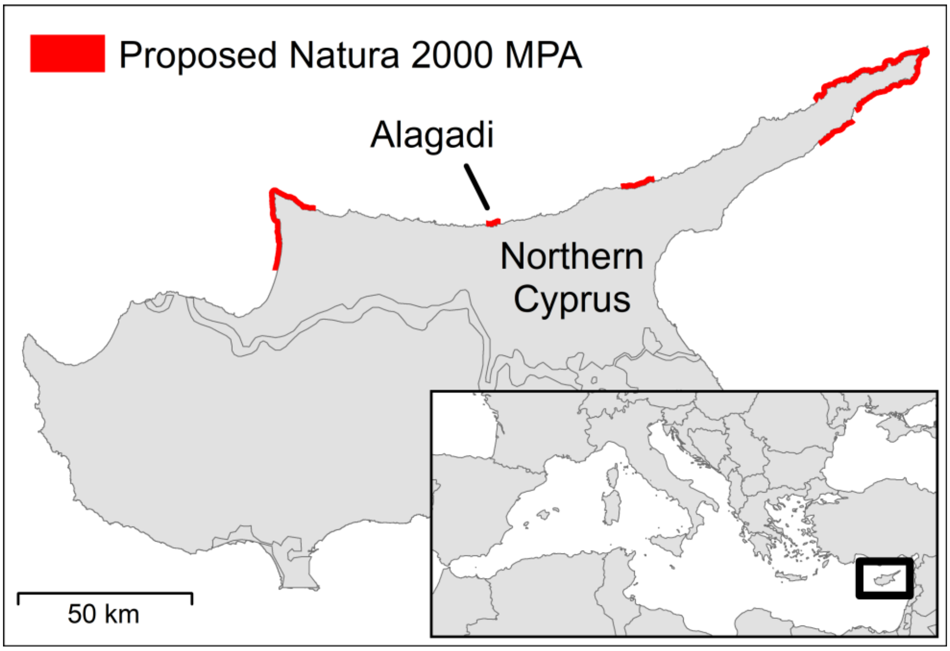

Figure 1. Location of study site in the Eastern Mediterranean and proposed Natura 2000 MPAs.

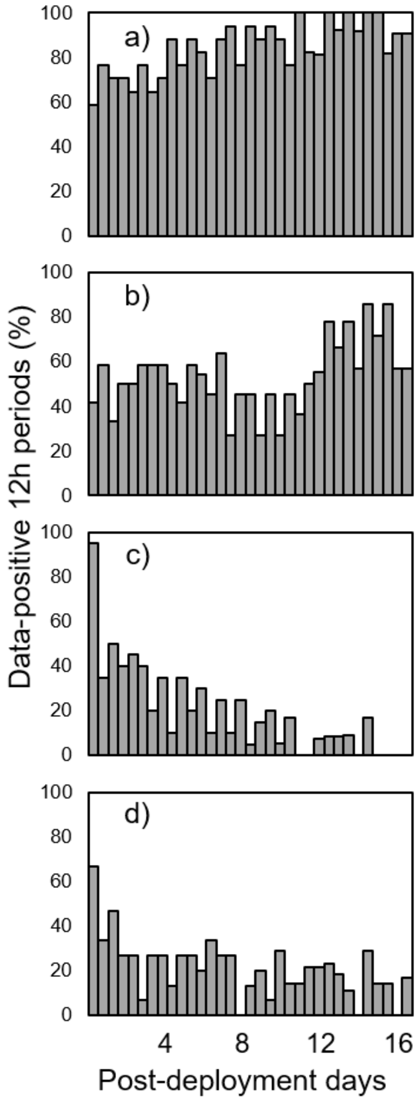

Fig. 2. Twelve-hour tracking intervals across study turtles at large for which data were available as a proportion of tracking intervals of turtles at large. Green and loggerhead turtles tracked by PTT (a and b respectively) and GPS (c,and d respectively). Data availability was temporally more consistent for PTT tracking compared to GPS tracking, where data were skewed toward the first days of tracking due to battery failures.

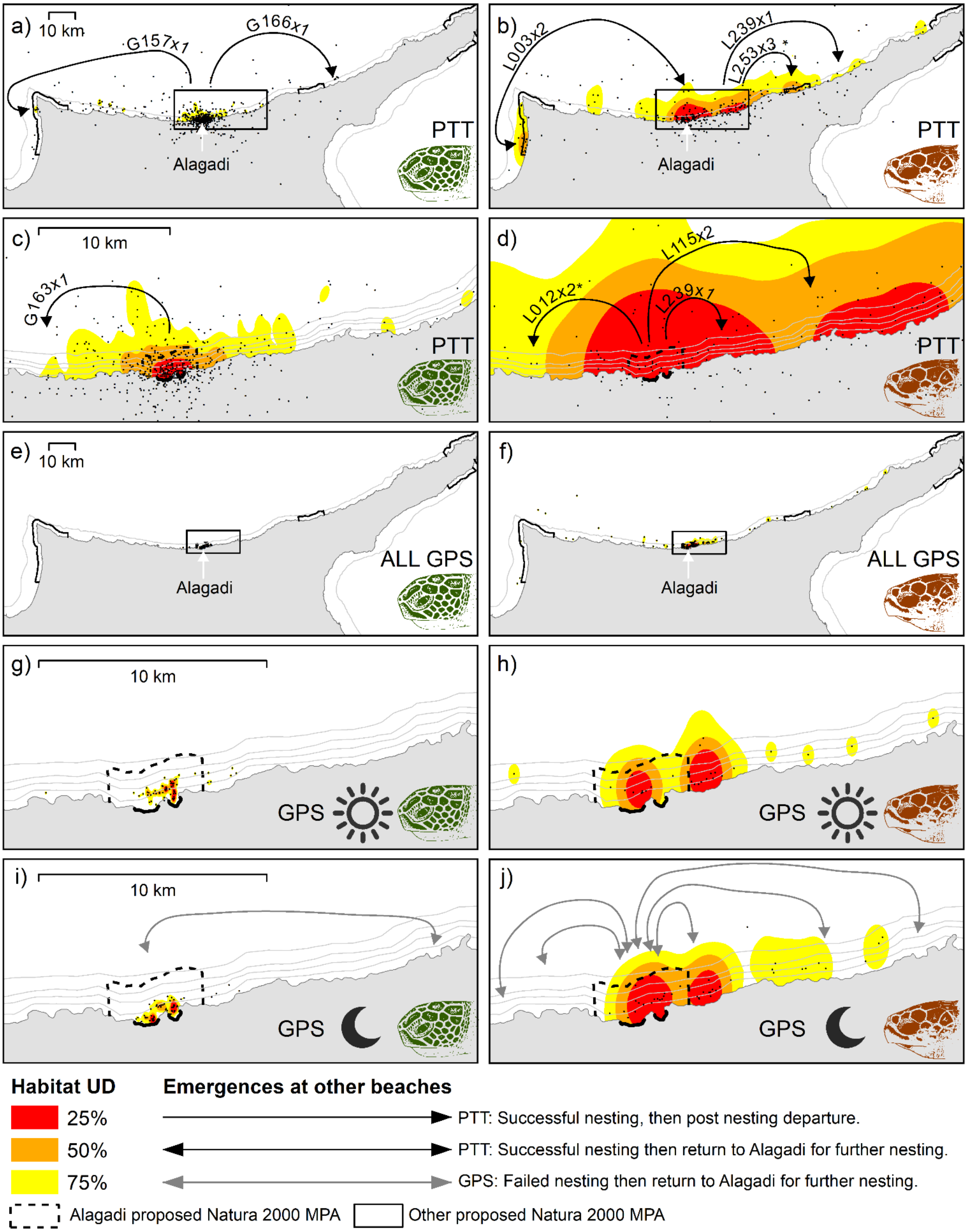
a)
10 km
G157x1
G166x1
Alagadi
PTT
b)
L003x2
L239x1
L253x3 *
Alagadi
PTT
c)
10 km
G163x1
PTT
d)
L115x2
L012x2*
L239x1
PTT
e)
10 km
Alagadi
ALL GPS
f)
Alagadi
ALL GPS
g)
10 km
GPS
h)
GPS
i)
10 km
GPS
j)
GPS
Habitat UD
25%
50%
75%
Emergences at other beaches
PTT: Successful nesting, then post nesting departure.
PTT: Successful nesting then return to Alagadi for further nesting.
GPS: Failed nesting then return to Alagadi for further nesting.
Alagadi proposed Natura 2000 MPA
Other proposed Natura 2000 MPA

Figure 3. Habitat utilisation distributions (UDs), filtered location data and schematic movements to alternative nesting sites (see legend for details) by species and tracking method. Left and right columns show green and loggerhead turtle tracking respectively and maps in the same rows are at equal scale. Argos PTT tracking of a) green turtles and b) loggerhead turtles, where insert boxes show the areas depicted subsequently at higher resolution for c) green turtles and for d) loggerhead turtles. GPS tracking of e) green turtles and f) loggerhead turtles, where insert boxes show the areas depicted subsequently at higher resolution for g) green turtles by day and h) loggerhead turtles by day and i) green turtles by night and j) loggerhead turtles by night. Thick black coastal embayments represent Alagadi nesting beaches. Bathymetric contours are 100 m in a-b, e-f and 10, 30, 50 and 100 m in c-d and g-j. *labels denote female ID and estimated number of clutches laid at distant site (see online appendix Table A4). See Snape et al (2016) for one loggerhead turtle, tracked by PTT which laid further clutches in the Antalya region of Turkey, not drawn here for clarity.

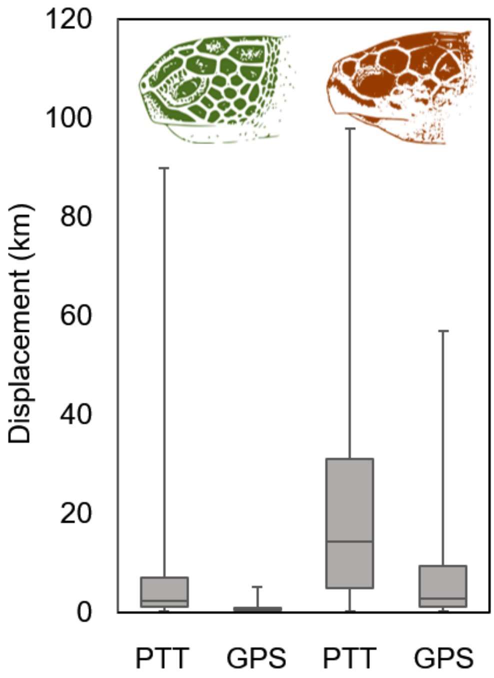

Figure 4. Displacement (km) values of PTT and GPS locations (one location per 12-hr period). Horizontal line on boxes indicates median value, upper and lower edges of boxes represent first and third quartiles respectively and whiskers represent range.

Table A1: PTT manufacturer and models of devices used in this study.

Female ID	Deploy date	PTT manufacturer	PTT Model
Green turtles			
G055	11/07/2003	Sirtrack	Kiwisat 101
G008	24/06/2004	Sirtrack	Kiwisat 101
G044	23/07/2004	Sirtrack	Kiwisat 101
G015	03/07/2009	Sirtrack	Kiwisat 101
G157	05/07/2009	Sirtrack	Kiwisat 101
G071	15/07/2009	Sirtrack	Kiwisat 101
G166	15/07/2009	Sirtrack	Kiwisat 101
G058	16/06/2010	Sirtrack	Kiwisat 101
G009	26/06/2010	Sirtrack	Kiwisat 101
G163	28/06/2010	Sirtrack	Kiwisat 101
G080	01/07/2010	Sirtrack	Kiwisat 101
G087	07/07/2010	Sirtrack	Kiwisat 101
G217	29/06/2015	Wildlife Computers	SPOT 293A
G252	29/06/2015	Wildlife Computers	SPOT 293A
G020	30/06/2015	Wildlife Computers	SPOT 293A
G201	30/06/2015	Wildlife Computers	SPOT 293A
G254	30/06/2015	Wildlife Computers	SPOT 293A
Loggerhead turtles			
L003	07/06/2005	Sirtrack	Kiwisat 101
L012	30/06/2006	SMRU	SRDL
L043	17/07/2002	Telonics	ST14
L043	05/06/2004	Telonics	ST18
L044	03/07/2002	Telonics	ST6
L111	24/06/2005	Sirtrack	Kiwisat 101
L115	13/06/2003	Telonics	ST18
L151	12/06/2001	Telonics	ST14
L212	05/06/2002	Telonics	ST6
L239	30/06/2005	Sirtrack	Kiwisat 101
L253	21/06/2006	SMRU	SRDL
L305	01/07/2009	SMRU	SRDL

Table A2: Summary of GPS tracker configurations. The dimensions of the trackers were 45 x 41 x 14 mm. Housing methods were 1) the tracker was inserted into a 100 x 50 mm pressure-tight streamlined sealed plastic housing and 2) the tracker was encased in multiple layers (to a thickness of approximately 5mm) of self-amalgamating tape.

ID	Operating hrs/week	GPS logging interval (seconds)	Motion detector	Housing type
G009	168	180	ON	2
G009	75	180	OFF	2
G009	75	180	OFF	2
G079	75	180	OFF	2
G079	112	240	OFF	2
G087	168	420	ON	2
G187	64	240	OFF	1
G192	168	120	OFF	1
G197	168	240	ON	2
G197	75	240	OFF	2
G206	168	120	OFF	1
G206	72	120	OFF	1
G211	168	30	OFF	1
G211	72	120	OFF	1
G212	168	120	OFF	1
G217	168	120	OFF	1
G218	168	30	OFF	1
G259	72	120	OFF	1
G264	168	30	OFF	1
G264	168	240	OFF	1
L012	168	300	ON	2
L111	112	300	OFF	2
L159	168	120	OFF	1
L246	168	180	ON	2
L276	168	30	OFF	1
L371	168	120	OFF	1
L383	168	120	OFF	1
L401	88	120	OFF	1
L429	168	420	ON	2
L431	112	300	OFF	2
L434	75	180	OFF	2
L434	112	420	OFF	2
L439	112	120	OFF	2
L439	75	180	OFF	2
L441	75	180	OFF	2

Table A3: Details of failed GPS deployments.

Female ID	Deploy date	Reason for failure	Housing method	Other INIs tracked
Green Turtles				
G261	27/06/2013	Did not return	1	0
G267	06/07/2013	Did not return	1	0
G262	13/06/2014	Did not return	2	0
G218	15/06/2013	Flooded	1	1
G259	13/06/2013	Flooded	1	1
G261	15/06/2013	Flooded	1	0
G079	22/06/2014	Flooded	2	2
G087	03/06/2014	Flooded	2	1
G218	27/06/2013	No data	1	1
Loggerhead turtles				
L003	02/06/2014	Flooded	2	0
L003	20/06/2014	Flooded	2	0
L012	01/06/2014	Flooded	2	1
L012	02/07/2014	No data	2	1
L111	27/06/2014	No data	2	1
L355	10/06/2013	Did not return	1	0
L386	18/06/2013	Tracker lost at sea	1	0
L398	23/06/2013	Did not return	1	0
L430	03/06/2014	Did not return	2	0
L431	04/07/2014	Did not return	2	1
L431	22/06/2014	Flooded	2	1
L432	05/06/2014	Did not return	2	0
L433	06/06/2014	Did not return	2	0
L434	07/07/2014	Did not return	2	2
L435	09/06/2014	Did not return	2	0
L437	11/06/2014	Flooded	2	0
L438	13/06/2014	Did not return	2	0
L441	05/07/2014	Flooded	2	1
L442	21/06/2014	Did not return	2	0
L444	24/06/2014	Did not return	2	0
L445	17/06/2014	Did not return	2	0

Table A4. Summary of satellite transmitter and GPS (I GOT U GT600) tag deployments included in this study. * For satellite transmitters, this is when the female made a post-nesting departure, for GPS this is the date on which the GPS (or final GPS if multiple INI were tracked) was retrieved. **For satellite transmitters, inter-nesting intervals are estimated according to the mean inter-nesting interval reported by Broderick et al. (2002) of 12.5d for green turtles and 13.4d for loggerhead turtles.

Female ID	Deploy date	Inter-nesting tracking period end*	Inter-nesting days tracked	Inter-nesting intervals**	Filtered locations	% data-positive 12-hr periods
Green turtles PTT						
G008	24/06/2004	21/07/2004	28	2	113	86
G009	26/06/2010	17/07/2010	22	2	89	91
G015	03/07/2009	26/07/2009	24	2	38	54
G020	30/06/2015	22/07/2015	22	2	224	100
G044	23/07/2004	05/08/2004	14	1	11	36
G055	11/07/2003	02/08/2003	23	2	195	98
G058	16/06/2010	20/07/2010	35	3	106	84
G071	15/07/2009	28/07/2009	14	1	21	54
G080	01/07/2010	23/07/2010	23	2	49	89
G087	07/07/2010	20/07/2010	14	1	55	82
G157	05/07/2009	24/07/2009	15	1	41	90
G163	28/06/2010	30/07/2010	33	3	106	86
G166	15/07/2009	10/08/2009	27	2	45	67
G201	30/06/2015	12/07/2015	13	1	111	92
G217	29/06/2015	21/07/2015	23	2	206	93
G252	29/06/2015	03/08/2015	36	3	244	94
G254	30/06/2015	11/07/2015	12	1	106	96
		Total:	378	31	1760	
Loggerhead turtles PTT						
L003	07/06/2005	24/07/2005	48	4	151	64
L012	30/06/2006	24/07/2006	25	2	21	38
L043	17/07/2002	28/07/2002	12	1	4	17
L043	05/06/2004	05/08/2004	62	5	83	54
L044	03/07/2002	16/07/2002	14	1	2	7
L111	24/06/2005	05/07/2005	12	1	15	42
L115	13/06/2003	10/07/2003	28	2	62	71
L151	12/06/2001	24/06/2001	13	1	2	8
L212	05/06/2001	21/06/2001	17	1	19	41
L239	30/06/2001	05/08/2001	37	3	68	51
L253	21/06/2006	27/07/2006	37	3	64	72
L305	01/07/2009	14/07/2009	14	1	2	7
		Total:	319	25	493	
Green Turtles GPS						
G009	04/06/2014	10/07/2014	36	3	27	15
G079	07/06/2014	11/07/2014	24	2	16	13
G087	17/06/2014	01/07/2014	14	1	3	10
G187	29/06/2013	09/07/2013	11	1	88	77
G192	07/06/2013	20/06/2013	14	1	16	14
G197	31/05/2014	12/07/2014	29	2	16	9
G206	11/06/2013	05/07/2013	24	2	68	26
G211	11/06/2013	06/07/2013	25	2	74	15
G212	05/06/2013	19/06/2013	14	1	13	13
G217	10/06/2013	15/06/2013	14	1	13	25
G218	15/06/2013	17/06/2013	11	1	56	33
G259	26/06/2013	09/07/2013	13	1	178	46
G264	11/06/2013	06/07/2013	25	2	276	48
		Total:	254	20	844	
Loggerhead turtles GPS						
L012	18/06/2014	02/07/2014	13	1	16	37
L111	13/06/2014	26/06/2014	14	1	5	21
L159	08/06/2013	22/06/2013	14	1	54	23
L246	15/06/2014	25/06/2014	13	1	19	9
L276	20/06/2013	02/07/2013	12	1	159	31
L371	08/06/2013	23/06/2013	15	1	40	19
L383	05/06/2013	23/06/2013	18	1	35	24
L401	24/06/2013	06/07/2013	12	1	121	77
L429	02/06/2014	18/06/2014	16	1	2	6
L431	04/06/2014	23/06/2014	19	1	18	15
L434	06/06/2014	06/07/2014	30	2	9	10
L439	17/06/2014	16/07/2014	27	2	24	20
L441	21/06/2014	05/07/2014	14	1	2	7
		Total:	217	15	504	

Chapter V: Assessing fishing intensity, resource dependency and marine traffic for small-scale fisheries operating in Mediterranean Marine Protected Areas and Marine Important Bird Areas

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Abstract

Although a global marine biodiversity hotspot, the Mediterranean is one of the most fishery-impacted regions of the world. The region hosts around 100,000 vessels, most of which are under 12 m in length. Due to their vast numbers, such small and numerous vessels are typically overlooked in research, monitoring and management, yet their biodiversity impacts are considerable. Meanwhile the oversight of small vessels tends to drive the marginalisation of the most vulnerable fishers in socioeconomic and political terms. Increasingly, industrial vessels are being tracked by Vessel Monitoring (VMS) or Automatic Identification Systems (AIS), with demonstrable results for fisheries sustainability, but, due to funding barriers, spatiotemporal data are rarely available for small-scale fisheries. For two years we followed the activity of 46 vessels representing 13 % of the Turkish Cypriot fleet using competitively priced off-the-shelf GPS trackers. After applying filters to isolate fishing activity, footprints were developed for fishing intensity, resource dependency and vessel traffic. To demonstrate the utility of these data in marine spatial planning, fisheries parameters are overlaid with relevant habitat data in the Karpaz Peninsula revealing potential fisheries impacts on protected sea turtles (*Chelonia mydas*), seabirds (*Larus audouini* and *Gulosus aristotelis desmarestii*) and seagrass beds (*Posidonia oceanica*). The management plans of two Marine Protected Areas were found to be ineffective and hotspots of fishing activity were spatially and temporally proximal to seabird nesting. The illustrative data layers, while useful to the Turkish Cypriot fisheries authorities in managing their fleet, demonstrates the feasibility of cheaply available technology for tracking small vessels at greater resolution than provided by VMS or AIS and at a much-reduced cost. The technique could be rolled out across small-scale fisheries to address uncertainty, develop policy and monitor important but neglected fishing communities.

Introduction

A third of global fish stocks are being extracted at unsustainable rates, according to the Food and Agriculture Organisation of the United Nations (FAO, 2018) and reconstructed catches suggest that landings could be far greater than those reported (Pauly and Zeller, 2016). Greater sustainability has been achieved through fisheries policy (Watson *et al.*, 2018), but to meet sustainability goals while also ethically considering the livelihoods of fishers, policy must be well informed (James *et al.*, 2018). Policy developers thus require detailed knowledge of fishing practices and hauls, only achievable through investment in research and monitoring (Stewart *et al.*, 2010; Maxwell *et al.*, 2013; Ferrigno *et al.*, 2017; Kantoussan *et al.*, 2018). There are 4.6 million fishing vessels in the World, and many countries support tens of thousands of small-scale vessels (considered here to be less than 12 meters in length or non-motorised (Chuenpagdee *et al.*, 2006; FAO, 2018). Despite their critical role in food security and in supporting the majority of fisheries livelihoods, least is known about practices of small-scale fishing operations (Jacquet and Pauly, 2008; Alfaro-Shigueto *et al.*, 2010). Perceived as too numerous and diverse to enable systematic reporting, small-scale fisheries monitoring is often neglected, a knock-on effect of which is their marginalisation, manifested through exclusion from policy processes, subsidies and sustainability schemes (Chuenpagdee *et al.*, 2006; Jacquet and Pauly, 2008).

Onboard observation has for decades been used to provide data needed for assessing fish stocks (Sabourenkov and Appleyard, 2005; Hulson *et al.*, 2011; Cadrin *et al.*, 2016), understanding bycatch of vulnerable species (Casale *et al.*, 2007; Delord *et al.*, 2010) and eliminating Ilegal, Unreported and Unregulated Fishing (IUU). Because of its considerable costs and inconvenience to industry, observer coverage is usually only applied to large-capacity vessels and even then, is limited and often not appropriately distributed among fleet segments (Dunn *et al.*, 2018). To complement observer programs by providing spatiotemporal information on fishing activities, Vessel Monitoring Systems (VMS; uses satellites to relay positional information on specific vessels), and Automatic Identification Systems (AIS; uses coastal or fixed marine base stations to detect individually identifiable VHF transmissions) are now used in many fisheries (reviewed by Dunn *et al*., 2018). The utility of remotely accessed spatiotemporal data has been increasingly diverse. For example recent studies have assessed the interaction of fisheries with threatened marine megavertebrates (Tew Kai *et al.*, 2013; Sztukowski *et al.*, 2017), with pipeline installations (Rouse *et al.*, 2017, 2018), modelled landings by fishing ground (Russo *et al.*, 2018), delimited fishery footprints (Witt and Godley, 2007; Jennings and Lee, 2012), and identified suspicious or illegal fishing behaviour (Ford *et al.*, 2018a, 2018b). Data handling tools have been developed to aid analysis of VMS data (Russo *et al.*, 2014) and it is possible to use algorithms to reliably separate and report on specific metiers (Russo *et al.*, 2011). Again, due to their cost, these systems are prioritised to large capacity vessels, often mandatory only for vessels >15 m length (Witt and Godley, 2007; Dunn *et al.*, 2018); for the great majority of vessels worldwide there is a continued absence of spatiotemporal information to inform their management.

Some progress has been made in recent years in advancing techniques toward an economically feasible spatiotemporal monitoring system in small-scale fisheries, but the techniques remain too expensive to be applicable in many fleets. In Scottish inshore fisheries (vessels ≤ 12 m) were equipped with AIS devices, the current market cost of which (three online quotes) is €637 to €979. In Andalucía, Spain, authorities installed Global System for Mobile Communications (GSM) linked Global Positioning System (GPS) devices to successfully monitor a small-scale fleet with in response to sustainability concerns regarding a specific small-scale fleet segment and target catch (Burgos *et al.*, 2013). The costs of this system included development of a control centre at €85,000, plus unit and annual service costs of €1,400 and €1,200 (respectively) per vessel. In Taiwan, Coastal radar surveillance systems that gather data on vessel position to 12 nm offshore, were used to provide high-resolution spatiotemporal data sufficient to define fishing locations, effort and landings per unit effort (Chang, 2014). In the Caribbean, off-the-shelf GPS data loggers, generally used for tracking sport and leisure (available for around €30 to €70), have been used to understand the behaviour of fishers, identifying area-restricted search patterns to identify when fishers were exploiting fish aggregating devices (Alvard *et al.*, 2015). In the Republic of Congo, similar GPS data loggers were distributed to participating fishers to provide information on their fishing behaviours, map fishing grounds and their community dependence (Metcalfe *et al.*, 2017).

Bycatch of threatened marine vertebrates in small-scale fisheries could equal or exceed the contribution of industrialized fisheries (Pechham *et al.*, 2007; Żydelis *et al.*, 2009). To address this, fisheries footprints are useful in that they can be overlaid on habitat use data (eg. telemetry or at-sea surveys), or modelled habitat data, to help identify potential bycatch hotspots (Chalmers *et al.*, 2014; Lucchetti *et al.*, 2016; Sztukowski *et al.*, 2017). The Karpaz Peninsula in North Cyprus has been identified by Birdlife International (Birdlife International 2019; Ramirez *et al*., 2017) as a Marine Important Bird Area (IBA) as it hosts Cyprus's only colony and the world's most easterly colony of the Audouin's Gull (*Larus audouinii*) and a significant breeding colony (> 50 pairs; lead author personal observations) of the Mediterranean shag (*Gulosus aristotelis desmarestii*). Both species are listed on Annex I of the European Union Birds Directive which requires member states to protect priority sites (http://ec.europa.eu/environment/nature/conservation/wildbirds/threatened/index_en.htm). Beaches of the Karpaz peninsula are among the most important for nesting of the Mediterranean green turtle (*Chelonia mydas*), supporting hundreds of nests annually (Stokes *et al*., 2015). Two potential Natura 2000 area Marine Protected Areas have been delineated to protect nesting green turtles, seagrass (*Posidonia oceanica*) beds and seabirds in this region of Cyprus. Within these Natura 2000 sites, management plans suggest that fishing with set nets should be prohibited (Snape *et al*., 2018b). But the degree to which fisheries depend on these designated MPAs and IBA are not known and this impedes their current and future effective management.

We worked closely with Mediterranean fishers in North Cyprus to gather spatiotemporal data via off-the-shelf GPS data loggers. Our aims were to demonstrate a tool to monitor small vessels, at costs that could realistically be met by global fisheries. To demonstrate the utility of the resulting data layers in marine spatial planning, we overlaid the resulting fishery layers on MPA and Marine IBA boundaries, important nesting beaches and *Posidonia oceanica* distribution data.

Methods

Study site

Polyvalent motorised vessels make up 72 % of all Mediterranean fishing vessels, with over 64,000 such vessels reported (FAO, 2016). These vessels typically use set nets (bottom-set gillnets and trammel nets), hooks and lines, traps and seins to target demersal (chiefly) and pelagic fish, molluscs and crustaceans. Northern Cyprus is a contested state of the European Union, governed by the Turkish Cypriot authorities, who do not permit traps nor industrialised fisheries using active gears such as trawls and purse seines (Ulman *et al.*, 2015; Snape *et al.*, 2018). The entire commercial fleet therefore consists of motorised polyvalent vessels of ≤ 12 m in length using longlines and bottom-set nets. Thirteen fishing shelters hosted 342 vessels in 2011 (Snape *et al.*, 2013; Fig. 1).

GPS deployment details

Forty-six vessels (median proportion of total tracked vessels by port: 13.8 %; 13.4 % of the total northern Cyprus fleet (Snape *et al.*, 2013)) were tracked from the thirteen ports from June 1, 2012, through May 31, 2014 (for study area and description of spatial and temporal coverage see Fig. 1). Vessels were selected with no prior knowledge of their vessel capacities or preferred methods, during workshops where captains (n: >126) were gathered in ports (Snape *et al.*, 2013). Off-the-shelf GPS data loggers (iGotU GT600; Mobile Technology; €49 each), were sealed in insulating tape and taped to the metal railings of the vessel canopy, usually below a protective tarpaulin that is stretched across the canopy to provide shade. The GPS loggers were programmed to collect a location every 2 minutes initially, extended to a maximum of 5 minutes through the study, to conserve battery life and reduce the logistical costs (fuel, mileage and time) of replenishing the devices. An integrated motion sensor was activated which allowed the devices to switch off data logging in port during relatively calm conditions, when the vessel was stationary, conserving battery life. Under these settings, the parameter limiting deployment duration was always battery life, and never data storage. Regular trips (usually monthly) were made to harbours by the lead author to replenish the devices with fully charged and formatted GPS loggers.

Extrapolation to fishing effort

To account for temporal and spatial variation in coverage (Fig. 1), data were extrapolated to total fishing effort by port and by month, and then summed across ports to create month maps for the fishery for each of the three parameters considered. To provide an estimate of fishing effort by port for each month, the total number of vessel days (port fleet size * number of days in month) was calculated for each month of the study according to available port vessel counts (Snape *et al.*, 2013). A scale factor (SF) was calculated for each port month as follows:

$$SF = 1 \ / \ \frac{VTDpm}{TVDpm}$$

where VTDpm is the total number of vessel tracking days for the port month and TVDpm is the total number of vessel days for the port month.

GPS data handling

Data logged pre- and post-deployment were removed from the 393 resulting GPS files during their initial download. All files were assimilated into a single complete data frame using the programming package R where, port IDs and vessel IDs were assigned and velocity between consecutive locations were calculated according to their relative displacement over time. Any data points assigned a speed over 60 $km.h^{-1}$ (maximum speed attainable by a 40 hp outboard engine) were removed and point data were then converted to line data.

Fishing intensity

From the complete vessel tracking data frame, datapoints that were considered to be representative of fishing activity (deployment or retrieval of set nets or longlines) were isolated according to vessel velocity (a common basic method for differnitatiating fishing behaviours; Burgos *et al.*, 2013; Russo *et al.*, 2014; De Souza *et al.*, 2016) where speeds of 0.8 to 4.9 $km.h^{-1}$ were considered representative of fishing activity, and retained. Locations assigned speeds below this threshold range are likely to result from periods of inactivity at sea, anchoring off the coast, or in port and speeds above this range likely result from taxiing quickly between fishing areas and to/from port (lead author personal observations). A 500 m buffer was allocated around the centre of each port to remove noisy data created by erroneous GPS points logged in port, and from the sheer volume of locations at the entrance to the port. Fishing events were separated according to three rules: 1. by time, where time between consecutive fishing location data points > 10 minutes; 2. by distance, where distance between consecutive fishing location data points > 1 km, and 3. by time and distance, where time between consecutive fishing location data points is > 10 minutes and distance is > 150 m. Separated fishing events were counted by pixel and exported to a raster layer by port month. Port-month rasters were viewed in ArcMap (10.3.1), where the Raster Calculator tool was used to multiply rasters by the calculated scaling factors (see section Extrapolation to Fishing Effort)). Raster Calculator was then used to sum all 24 extrapolated port-month rasters for each port, and then to sum across ports to account for overlaps of fishers from different ports to a single raster representing the entire fleet effort over the two-year study period. Finally, we divided the total number of fishing events by two, to provide an estimate of sets rather than fishing events (which include both hauls and sets).

Resource dependency

The number of individual vessels that occurred in each pixel was summed for each port from the complete vessel tracking data frame, according to individually specific vessel ID numbers and exported to a raster of port resource dependency. Port resource dependency rasters were then summed to account for overlapping resource dependency between vessels from different ports.

Traffic

From the complete vessel tracking data frame, track lines transecting pixels of 100 m by 100 m were summed for each port and month. Port-month data were then extrapolated using the method described in section 1.4.

Finally, all data were mapped using 10 natural breaks (Jenks natural breaks optimisation; de Smith et al., 2009).

Fisheries overlap with critical habitats, Marine IBAs and MPAs

To exemplify overlap of fisheries and critical habitats we overlaid our three fisheries parameter maps onto available habitat data for the Karpaz Peninsula, the easternmost point of the island. Marine IBA boundaries were provided by the North Cyprus Society for Protection of Birds and Nature (KUŞKOR) and Birdlife Cyprus whose joint monitoring led to the designation of this site. MPA boundaries are as per Snape *et al* (2018b). Remotely sensed seagrass data are derived from images taken by the Ikonos 2 earth observation satellite at 4-m resolution and processed using ERDAS Imagine software. Green turtle nesting beaches are as described in Kasparek et al (2001). Monthly fishing intensity raster data were plotted in the Marine IBA around the Kleides Islands and considered against seabird temporal occurrence and phenology data for these colonies (Flint and Stewart 1983).

Results

Fishing intensity

Fishing preferentially occurred within the 100 m bathymetric isobar across all coasts (Fig. 2a). On the north coast, most effort occurred between 50 and 100 m whereas on the east and west coasts, most fishing occurred below the 50 m isobar. Fished areas were narrow (typically to 3 km offshore) on the north coast, and broader on the east and west coasts (typically to 4 to 6 km offshore) where shallower gradients provided broader areas of preferred fishing ground. Fishing intensity hotspots tended to mirror the distribution of vessels, with the areas serving the largest number of fishers, also hosting the greatest number of sets. Particularly intense fishing occurred in Famausta Bay where we estimate up to 1600 sets per 100 m by 100 m pixel were made off ports 1 and 2 during the study period and on the north coast off ports 10 and 11 (Kyrenia and Lapta). In both zones, considerable areas were fished at > 310 sets. In areas of the Karpaz peninsula remote from ports, fishing was spatially continuous and, in some areas, intense, probably facilitated by the availability of suitable anchorages that provide protection from prevailing westerly winds. Conversely, the West coast was least intensively fished, with only one moderately sized port and with no suitable anchorages.

In general, patterns of fishing intensity were parallel to the bathymetric contours which is as described previously in onboard observations of set nets in North Cyprus, where fishers set an average of 2 km of net per fishing trip, following bathymetric contours according to depth sounders (Snape *et al.*, 2018). Bathymetric bands were clearly targeted resulting in discrete bands of fishing activity, which may represent the habitat preferences of target catch.

Resource dependency

Some sites were used by between 70 and 97 vessels (Fig.2b), again in Famagusta Bay (ports 1 and 2) and off Kyrenia and Lapta (ports 10 and 11; Fig.

2b). High resource dependency mirrored high fishing intensity, suggesting collective awareness of the more valuable fishing sites and similar fishing behaviour among vessels.

Traffic

Each port was defined by a high rate of vessel traffic, dissipating towards commonly used fishing grounds, where areas of high fishing intensity and resource dependency also produced high levels of traffic (Fig. 2c).

Overlap with established marine conservation areas in Karpaz Peninsula

Fisheries use the Karpaz Peninsula MPAs and Marine IBAs relatively heavily and ubiquitously, clearly overlapping with *Posidonia oceanica* beds across much of the two MPAs (Fig.3). Of the order of 600 to 900 sets were made annually in some areas of both reserve types (Fig. 3b) and 34 to 40 vessels operated off the cape (Fig. 3c). Fishing intensity was relatively low in the areas directly bordering sea turtle nesting beaches, where green turtles are likely to be aggregating (Snape *et al*., 2018b). However, fishing did occur off all nesting sites with 214 to 309 sets made annually in proximity to some protected green turtle nesting sites. Vessel traffic was heavy in front of nesting beaches in the south Karpaz MPA (500 – 1000 vessel passes per year; Fig. 3d). Fisheries hotspots occurred in very close proximity to seabird colonies off the cape (Fig. 3b) and these sites were used by the most vessels (Fig. 3c). Between 144 and 309 sets were made annually in the waters directly off Kasteletta and Zinaritou Islands (Fig 3b). All of these sets were made between March and August, overlapping entirely with the nesting of Audouin's Gulls and with much of the breeding season of Mediterranean shags (Fig. 4).

Discussion

This research addresses a worldwide call to improve certainty of small-scale fisheries activities and is one of the first studies to produce a fisheries footprint for single geopolitical region. As a tool the technique could be further used to undertake long term monitoring and for one-off studies such as this, to rapidly gather data and to assess resource use and fishing intensity. The illustrative footprint data were not costly to collect (GPS costs: c €49 per vessel plus spares total €2,695; Fuel and mileage: €500 - €1000 this study) and are relevant in the establishment and zoning of Marine Protected Areas and in Marine Spatial Planning in providing information on the "anatomy" of fishing grounds (Jennings and Lee, 2012). The fine temporal resolution of GPS locations (≤ 5 min) presents opportunities for fine-scale interpolation beyond that provided for by VMS systems (Katara and Silva, 2017), to isolate complex vessel behaviours and therefore to separate out sets of different métiers (longlines/set nets applied to various target species; Russo *et al.*, 2011). The broader potential applications of these data are therefore diverse and could be applied to stock assessment and management, conservation of vulnerable taxa, ecosystem research, fishery economics and enforcement.

Stock assessments and management

Establishing a system for estimating and monitoring fish extraction is an integral part of sustainable fisheries management (Shepperson *et al.*, 2018). Fishermen in the study region are not obliged to report their landings, there is therefore no active stock assessment or monitoring. Using onboard observers or self-monitoring (eg. logbooks) to cover a proportion of the total fishing effort (trips), with effort established using analysis of GPS tracking data (number of trips, sets, soak times etc), it would be possible to construct a detailed assessment of total landings by species (Russo *et al.*, 2018), potentially allowing an estimation of the spatial distribution of fish catches (Lee *et al.*, 2010).

Conservation of vulnerable taxa and habitats

Using the same methods as described above (onboard observers, logbooks etc), fishing effort extracted from vessel tracking data could also be used to extrapolate bycatch per unit effort estimates, to understand total captures of vulnerable species. A program has now been established in the study area with the support of the MAVA foundation (http://mava-foundation.org/) to assess bycatch of vulnerable species, with fishers and onboard observers monitoring catches of all species. Effort statistics extracted from our tracking data may be used in extrapolating catches by landing site/fishing site. Combining GPS tracking with remote monitoring, such as continuous filming during landings (Bartholomew *et al.*, 2018), or by providing cameras to fishers to log their bycatch of vulnerable taxa (Snape, 2015), could also provide useful information on species dispersal and spatiotemporal patterns of bycatch.

Some threatened marine vertebrates have become dependent on fisheries, for example seabirds which scavenge discards (Tew Kai *et al.*, 2013) and cetaceans that depredate gears (Snape *et al.*, 2018). Biologging data can be used to assess the behaviour of such species in relation to fisheries, according to footprint data, to examine overlaps and to predict the impact legislative fisheries changes on their populations (Tew Kai *et al.*, 2013). Equally, habitat use data can be overlaid with fishery footprints to identify potential bycatch hotspots and develop mitigation.

The study shows that fishing is prevalent in two identified MPAs and in a Marine IBA. Interactions including vessel strikes to sea turtles and bycatch of sea turtles and seabirds could be occurring in these reserves. And resource competition with seabirds could be of conservation concern. By splitting fishery footprints temporally, to examinine spatial changes in fishing effort against the phenology of seabird nesting, the study reveals a high potential association between fisheries and nesting seabirds. Hotspots of fishing occurred during May – July at Kasteletta and Zinaritou islets, when Audouin's gulls are incubating and chick-rearing, and when juvenile Mediterranean shags are foraging (Flint and Stweart 1983). This high temporal and spatial association may be having negative effects on either Auduoin's gulls or Mediterranean shags. Audouin's gulls can be entangled on longlines as bycatch (Birdlife International 2015) and Mediterranean shags can be entangled and drown in set nets (Birdlife International 2018). Either of these methods are likely to be used by this fishery (Snape et al., 2013) in close proximity (tens to hundreds of meters) during this sensitive reproductive period, possibly resulting in some level of mortality. Depletion of prey resources around these colonies may also negatively impact breeding success. Conversely, either species has shown to benefit from foraging on discards and Audouin's gull in particular actively follows small-scale fishing vessels in the study area to exploit this resource (lead author personal observations). Audouin's gull at the Kleides islands has undergone a considerable decline in recent decades (Hellicar et al., 2016). Understanding the nature of fisheries actions in this Marine IBA and MPA using onboard observers and telemetry of foraging adults and fledged juveniles, should therefore be a research priority. Equally, tracking of adult nesting green turtles should be undertaken to better assess the potential for sea turtle bycatch and boat strikes. Once the nature of these interactions is understood, zoning within the reserves could be achieved.

Posidonia oceanica is an endemic plant to the Mediterranean and is very important for the region's ecology, because it forms habitat for many species including sea turtles (Pergent et al., 2016). The species has declined and been degraded across over a third of its global distribution during the last 50 years and consequently MPAs have been established to protect posidona beds. The two MPAs in the Karpaz Peninsula include a strict protection zone to 1.5 km offshore or to the 35 m bathymetric contour. These zones are specifically to protect *Posidonia oceanica*, by eliminating fishing using set nets and trawls, anchoring and motor craft where it occurs (Fuller et al., 2009a, 2010b). The study shows that the MPAs in Karpaz are not effective in providing the intended protection, as up to 40 fishing vessels are using these zones, chiefly for set net fisheries and a number of anchorages are established.

Ecosystem research

At three sites of 0.05 – 0.16 km^2 in Famagusta Bay, 900 - 1600 sets were made during the two-year study, by up to 97 fishers, equivalent to 800 sets annually or on average more than two sets per day. Such intensively fished sites may be spawning grounds for migratory species which aggregate seasonally (eg. *Spicara maena, Spicara smaris and Boops boops*), when they may be exploited with multiple gillnet sets per fishing trip, with multiple vessels working the same site at the same time (lead author personal observations), with no catch or effortquotas. These habitats clearly host significant fish biomass and may be of conservation importance and our data layers could be used to explore these features in more detail. VMS data have been used to identify historical hotspots of fishing at "reef-scales", showing benthic conditions to coincide with CPUE patterns (Jalali *et al.*, 2015).

Economics

The North Cyprus authorities provide subsidies to fishermen to support the sector. The subsidies are given to registered professional fishermen but the available budget is spilt equally among the fleet and does not account for time spent at sea. A common complaint of fishermen we worked with was that some vessels rarely left the harbour, yet their owners claimed the same subsidies as themselves while being employed in an unrelated sector. For less than €17,000 could fit all vessels with GPS equipment and use officers already employed at regional offices to make monthly harbour visits. This way subsidies could be divided according to time spent actively fishing (for example as per in Taiwan where VMS is used for this purpose (Chang, 2016). To avoid tampering, an organisational stamp or signature could be used on the insulation tape used to fix the GPS in place, so that officers could understand when devices had been tampered with. Alternatively, a locked housing could be produced. Meanwhile onboard observation of a sample of vessels could be used to accurately assess parameters such as gear damage by metier, fuel consumption, income from landings, to truly understand financial turnover of fishing operations. Such efforts could be used to address a funding gap between small-scale and industrial sectors (Jacquet and Pauly, 2008).

Enforcement

VMS was conceived with the intention of enforcing fisheries regulations (Lee *et al.*, 2010). In this context the ideal scenario is to have real time data on the distribution and activities of vessels, which is where AIS and VMS are more powerful. But regulatory responses to illegal fishing operations could be issued using this GPS data, for instance fishing in closed areas and by developing algorithms for detecting suspicious or illegal fishing behaviour (Ford *et al.*, 2018a, 2018b).

Caveats

The North Cyprus fishing fleet is relatively small with 300 to 400 vessels. Complete compliance in larger countries could be more difficult, in particular in small-sclae fisheries that are manages even more loosly with larger numbers of smaller boats, particularly where boats are removed from the water between fishing trips and so are not present in harbours for regular inspections.

As no landings data were available, it was not possible to infer and map Catch Per Unit Effort (eg. as per Burgos et al., 2013). However, the value of collecting accurate landings data both for target and non-target catch should be condisered when planning similar such studies. Effort could also be made during analysis to standardise methods and raster pixel sizes to draw comparisons in fishing effort between different fisheries/studies.

Conclusion

Many Cypriot fishers appreciate that their livelihoods could be safeguarded and enriched through sustainable fisheries management, many are aware that a healthy ecosystem is key to sustainable fishing and have shown extraordinary willingness to engage with researchers to bring this about through a) willingly providing for their own monitoring (current study) and b) reporting their bycatch of vulnerable taxa (Snape et al., 2013, 2018b). The illustrative data layers presented here will be of use to authorities and planners in assessing the economic impact of establishing Marine Protected Areas, including no take zones. These are required in order to protect vulnerable species such as the Mediterranean monk seal, *Monachus monachus,* which uses breeding sites across the coast (Gucu *et al.*, 2009), but which are particularly susceptible to mortality as bycatch in set nets (Karamanlidis *et al.*, 2008), to protect sea turtles of important nesting sites (Snape et al., 2018 in press) and to support breeding Audouin's Gulls, *Larus audouinii*, and Mediterranean Shags, *Gulosus aristotelis desmarestii*, within the islands only Marine Important Bird Area (Ramirez *et al.*, 2017). However, the available distribution data for these vulnerable taxa within the existing and potential reserves (except for breeding sea turtles at Alagadi; Snape *et al*., 2018b) is insufficient for detailed marine spatial planning, therefore habitat use studies are called for here, to prioritise bycatch mitigation while minimising the impact on industry. Considering that Karpaz Peninsula is remote from major human populations and so is economically marginalised, a high human community and cultural dependence on fishing should be considered due to low levels of alternative employment.

Turkish Cypriot fishers are increasing their set lengths to maintain landings in response to declining catch rates (Ulman *et al.*, 2015), while dolphins (*Tursiops truncatus*) are increasingly depredating sets in the face of declining carrying capacity (Snape *et al.*, 2018). Therefore, toward establishing and enforcing fishing limits to maintain stocks, particularly at fish breeding areas that are currently targeted, monitoring of landings should be established across all ports, with priority at the ports of Famagusta, Boğaz (Famagusta Bay), Lapta and Kyrenia (North coast) where the study found fishing intensity to be particularly acute. With long term GPS monitoring in place, responses of industry to such regulation could be accurately assessed (Watson *et al.*, 2018).

The Turkish Cypriot fishery is an appropriate case sample of the Mediterranean polyvalent segment. Therefore, the study demonstrates a relatively simple and cost-effective means why which information could be generated across the region.

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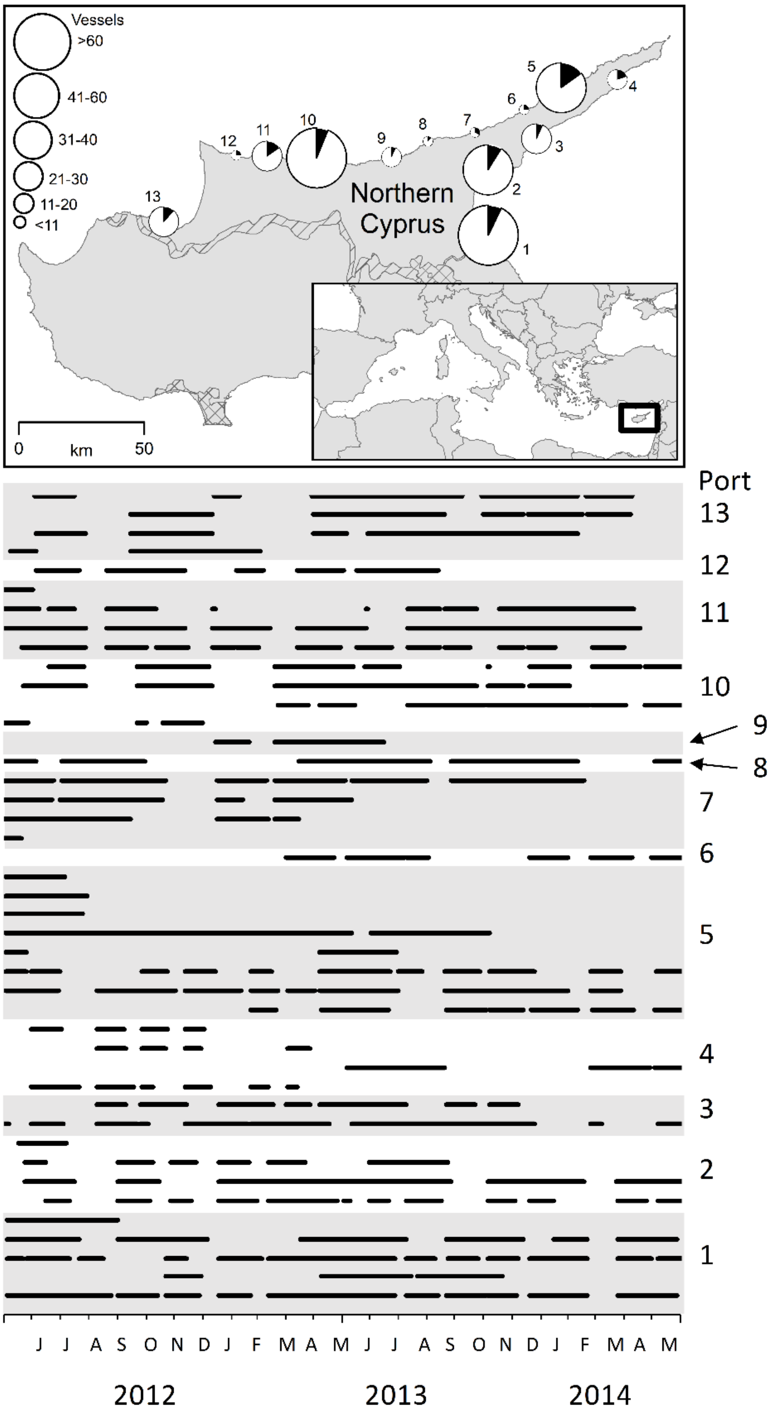
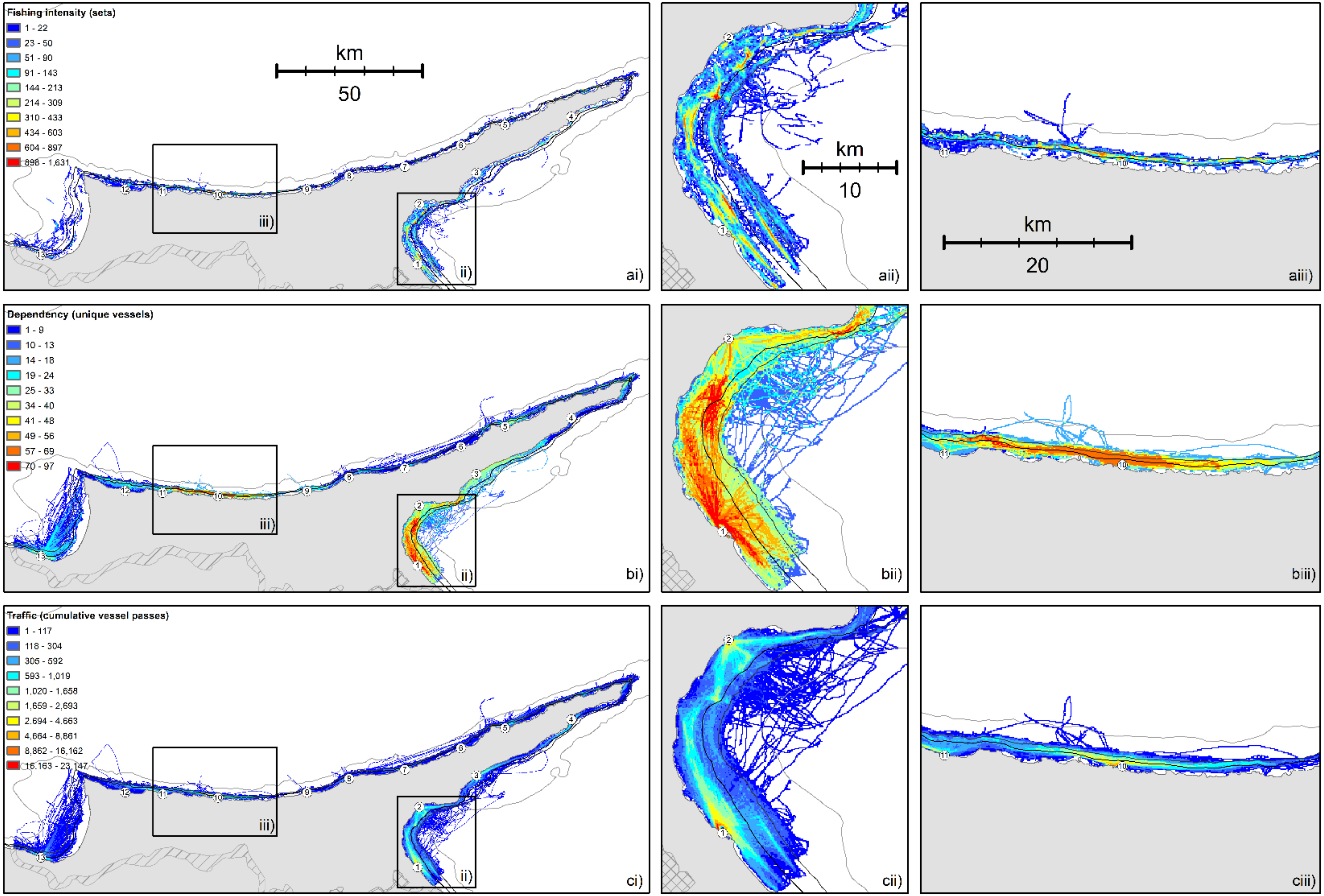


Figure 1. Map showing study site in the Mediterranean. Fishing harbours in Northern Cyprus are depicted by pie charts where black indicates the percentage of vessels tracked, and where the size of the pie is scaled to the number of vessels reported by Snape et al (2013 (Snape et al., 2013)). Broken horizontal black bars represent temporal tracking coverage of vessels in ports 1 – 13 (see vertical axis) by month (horizontal axis).



Fishing intensity (sets)
1 - 22
23 - 50
51 - 90
91 - 143
144 - 213
214 - 309
310 - 433
434 - 603
604 - 897
898 - 1,631
km
50
iii)
ii)
ai)
km
10
aii)
km
20
aiii)
Dependency (unique vessels)
1 - 9
10 - 13
14 - 18
19 - 24
25 - 33
34 - 40
41 - 48
49 - 56
57 - 69
70 - 97
iii)
ii)
bi)
bii)
biii)
Traffic (cumulative vessel passes)
1 - 117
118 - 304
305 - 592
593 - 1,019
1,020 - 1,658
1,659 - 2,693
2,694 - 4,663
4,664 - 8,861
8,862 - 16,162
16,163 - 23,147
iii)
ii)
ci)
cii)
ciii)

Figure 2. Total number of a) fishing sets, b) unique vessels and c) cumulative vessel passes occurring in pixels (Size: 100 m by 100 m). Ports are indicated by white dots and numbered according to Fig. 1. Bathymetric contours are 50, 100 (black), and 500 m (grey). ii and ii show expanded maps (according to areas demarked by boxes in i) of heavily fished areas on the north coast off ports 10 and 11 and in Famagusta Bay off ports 1 and 2.

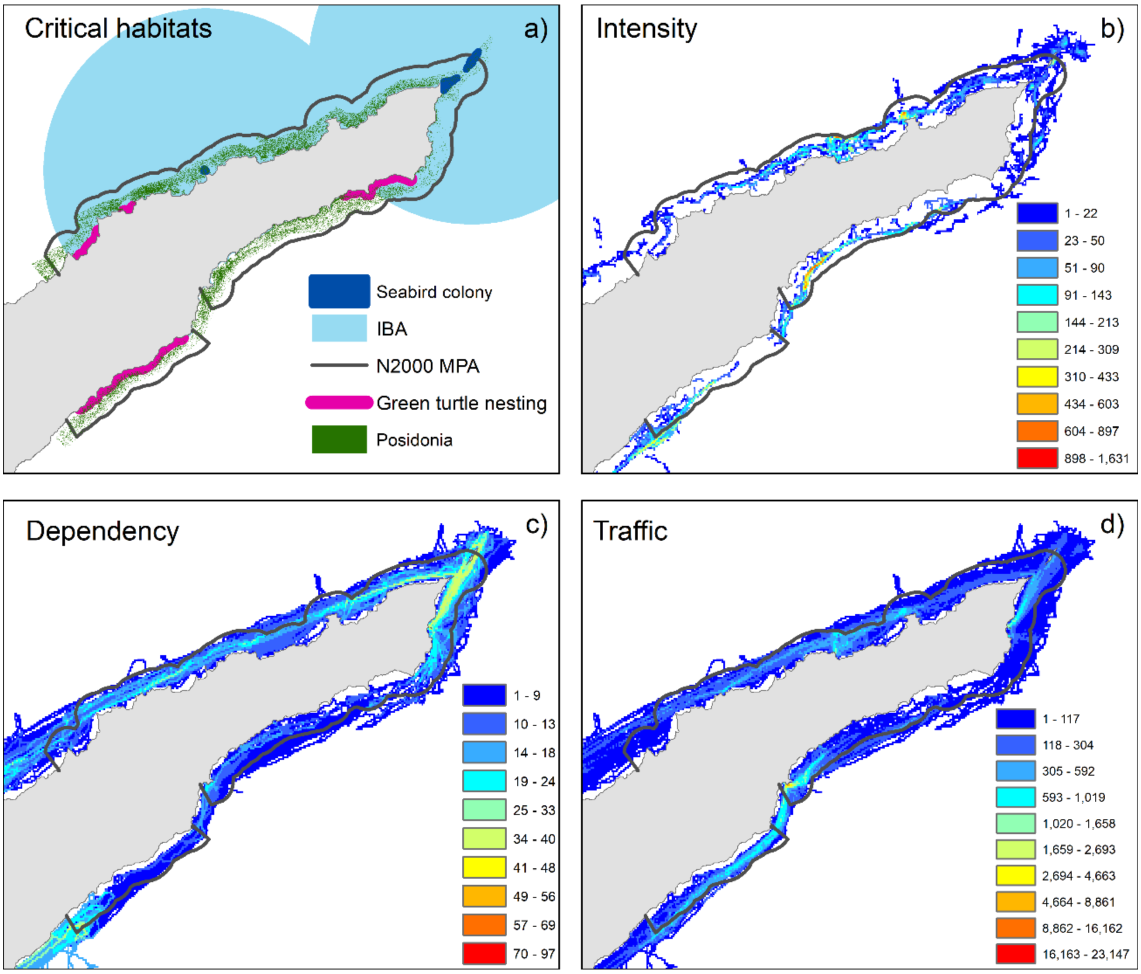


Figure 3. a) Seabird nesting colonies, the boundary of Cyprus's Marine Important Bird Area (IBA), two Natura 2000 Marine Protected Areas, green turtle (*Chelonia mydas*) nesting beaches (mean annual nesting numbers = >50 nests annually) and distribution of *Posidonia oceanica* beds in the Karpaz peninsula, b) fishing intensity (annual sets), c) socioeconomic dependence (annual unique vessels) and d) marine traffic (cumulative annual vessel passes).

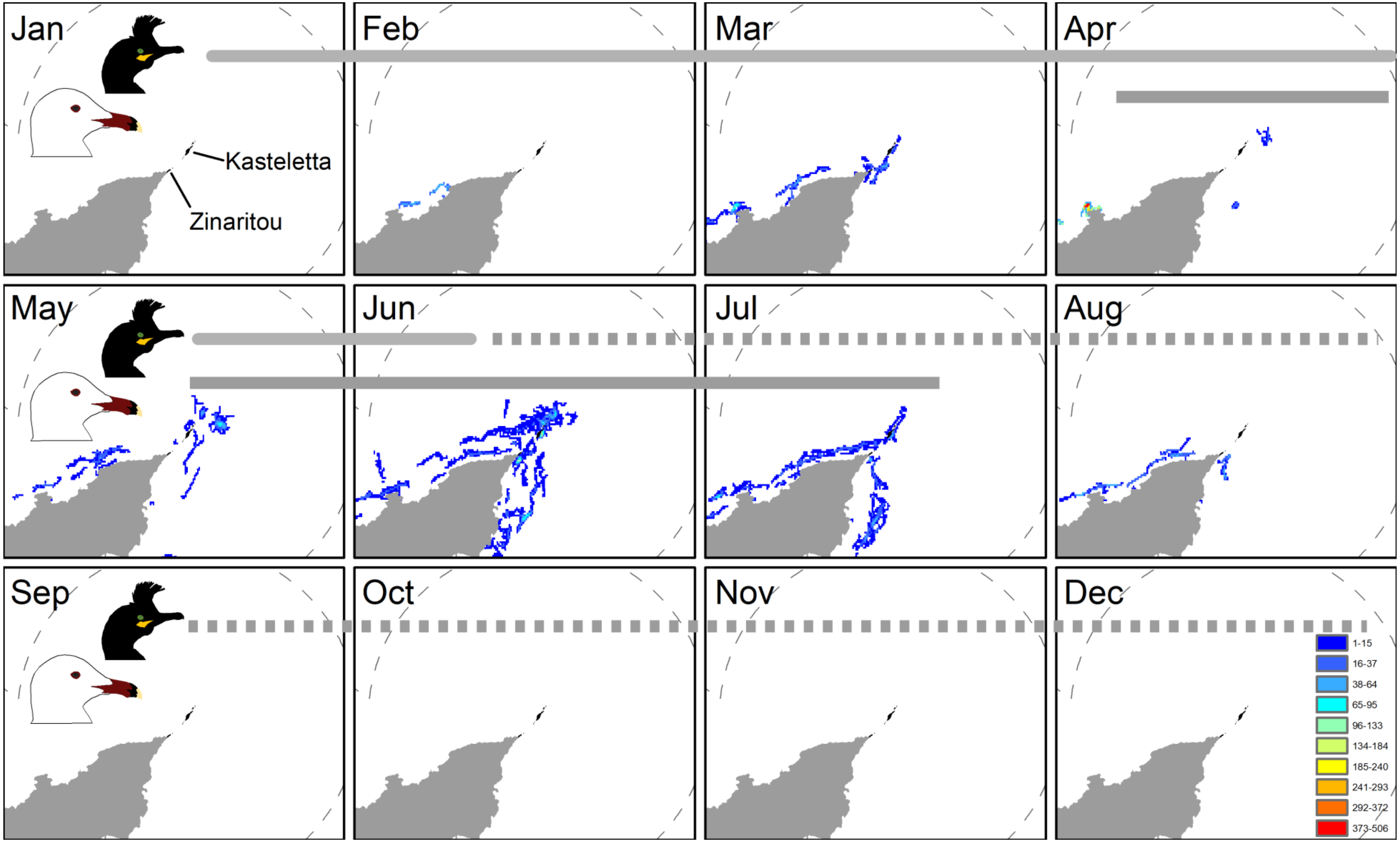


Figure 4. Fishing intensity by month off the Apostolos Andreas cape of Karpaz Peninsula showing build-up of fishing activity around the Kleides Islands Zinaritou and Kasteletta, the main breeding sites of protected Mediterranean shag and Audouin's Gull. Solid horizontal line indicates species breeding season, broken line indicates species present at colony.

Conclusion

At the national level, the thesis provides information that will enable the Animal Husbandry Department of the Turkish Republic of North Cyprus Ministry for Natural Resources and Agriculture to address a number of problems faced by the fishery. The author makes the following recommendations to their fisheries constitution.

Sea turtles

Protecting the breeders

Since trammel nets and demersal longlines are the main concern for bycatch of sea turtles (Chapter I), which we have seen are foraging across the Eastern Mediterranean (Chapter II; Stokes et al., 2015) these gears should be banned between April 20 through August 1 in core protection areas established directly in front of major nesting sites (for nesting numbers see project reports of the Marine Turtle Conservation Project and for recommendations for defining major nesting areas see methods of Casale et al., 2018). For major loggerhead turtle nesting sites and mixed species nesting sites, core protection zones should extend to the 35 m bathymetric contour (Chapter 4). For major green turtle nesting beaches protection zones should extend to the 15 m bathymetric contour (Chapter 4). Core protection zones for nesting turtles should buffer the designated nesting areas by 500 m.

Protecting the foragers

The lack of adult or large juvenile green turtles in strand and bycatch samples and the apparent high mortality of green and loggerhead turtles caught in more recent bycatch studies (a dedicated onboard observer survey managed by the author suggests > 2000 green turtles are hauled per year), are of concern. Strand and bycatch necropsy results show that both species are actively feeding in North Cyprus waters year-round, where they are caught as bycatch (Palmer et al., in prep). Green turtles that settle to develop in North Cyprus fishing areas having undergone pelagic development, are therefore either not reaching adulthood due to low survival probabilities, or are migrating away from Cyprus at around 40 – 50 cm CCL (Chapter I and subsequent unpublished strand/bycatch data). Given that bycatch and stranded carcasses usually have full stomachs (Palmer et al., in prep) and show good body condition (high fat content), the former scenario appears more likely. Green turtles in North Cyprus fishing areas are likely fished out shortly after recruitment. This hypothesis is supported by satellite tracking studies from nest sites; no adult green turtles have ever been tracked to the foraging grounds in North Cyprus that are shown here to be used by small juveniles (Stokes et al., 2015; lead author unpublished work (an additional 10 adult green turtles tracked from rookeries in Karpaz Peninsula, North Cyprus)). The presence of large juvenile and small adult loggerhead turtles in bycatch and strand samples, reflects their later ontogenic shift from pelagic to neritic habitats (Casale et al., 2012). The fact that very few large loggerhead turtles occur in bycatch and strand samples could be cause for similar concern, and similarly very few loggerhead turtles tracked from nesting sites have remained to forage, despite the apparent availability of foraging habitat.

Sea turtle bycatch appears to occur around the coast, where in addition to breeding turtles, migrating and foraging turtles will be impacted. Therefore, mitigation measures should be considered for fishers operating at all ports and with priority to those using trammel nets to target siganids (Chapter I). These gears have been shown to be used in shallow waters favoured by sea turtles, in particular green turtles which have an elevated conservation status. However, the target species of siganid trammel nets, *Siganus luridus* and *Siganus rivulatus*, are themselves invasive species with negative impacts on benthic habitats including seagrass beds, and to preserve biodiversity, it is recommended that fisheries are established to target these species (Sala et al., 2011). This presents a serious conservation dilemma. These species are also of high commercial value, so eliminating siganid fishing will not likely be supported politically.

In order to maintain siganid fishing while significantly reducing sea turtle bycatch, investments are needed to study the efficiency of alternative methods with lower bycatch, or bycatch reduction technology (BRT) for siganid trammel nets. BRT trials and net modifications in set net fisheries were reviewed by Gilman et al. (2010). They found that net illumination using green LED lights, decreasing net height, and reducing the number of or eliminating floats resulted in lower sea turtle bycatch rates. Subsequent studies using green and UV spectrum LED lights to illuminate set nets have subsequently been found to reduce green turtle (Wang et al., 2013) and loggerhead turtle bycatch significantly (>50 %), with a revent study showing success in the Mediterranean (Virgili et al., 2018).

However, trammel nets are by design, non-target specific and also preferentially catch other threatened species (lead author observations) including juvenile dusky grouper (*Epinephelus marginatus*) and elasmobranchs (eg. *Raja spp, Squatina squatina, Squatina oculata, Oxynotus centrina, Gymnura altavela*), nearly all of which have unfavourable IUCN redlist status in the Mediterranean region. Since these nets they are made of strong materials and are tall, they are also likely a threat to Mediterranean monk seals (*Monachus monachus*; Karamanlidis et al., 2008). In Lebanon, traps baited with algae are traditionally used to target siganids (Sacchi and Dimech 2011) and a current study is testing fish traps as an alternative to set nets to mitigate bycatch of elasmobranchs (EastMed 2018). Using the experience of Lebanese fishers, target-specific traps could therefore be developed and trialled, in North Cyprus as a multi-taxa bycatch solution that might eventually replace or reduce the prevalence of bycatch heavy siganid trammel nets as the preferred metier for this target.

Amateur fishers using small boats with outboard engines are permitted to use restricted amounts of set nets and longline gears. Set nets are limited to two 200 m sections. However, it is a great complaint of professional fishermen that set netting is permitted without a professional licence. The lead author has observed amateur fishermen flouting a minimum depth limit of 5 m, even setting nets by hand from the shore or by swimming. More than the minimum set length is often used and the chief metier used by amateurs is 28 – 32 mm trammel nets targeting siganids; enhabiting shallow waters close to shore they are the preferred target for the smallest capacity vessels. Amature gears are often left to soak overnight, i.e. fishers set late afternoon and haul in the morning, maintaining a day job in their profession, while apparently profiting from sales of fish. These long soak times are likely to result in high mortality rates for any bycaught vulnerable species. Such small boats are numerous and particularly difficult to account for as they can be trailered from towns and villages to any coastline. Therefore, to support professional fishermen and as a first step toward reducing sea turtle mortalities, permission for amateur fishermen to use set nets should be removed from the national fisheries constitution.

Safeguarding livelihoods and environmental sustainability: the win-win situation for dolphins, turtles, fishers and other stakeholders.

Industrialised fisheries such as trawling are not permitted by the TRNC authorities in order to safeguard fisheries resources for a larger fishing community using lower impact gears, rather than a small number of corporations. This is a great achievement and fisheries sustainability and biodiversity are surely better off without introduction of such methods. However, chapters III, V and a previous study by Ulman et al. (2014), suggest that fishermen are increasing their efforts year on year for lower and lower catch rates per unit effort. As discussed in chapter III, this is creating a vicious circle between fishers and dolphins as the compete for fewer and fewer fish. Chapter V has shown that in some areas fishing is intense and that there are, in effect, no Marine Protected Areas in North Cyprus. The tragedy of the commons is clearly in effect here; as there are no regulations in place to limit fishing with the permitted methods, every fisher is compelled to exploit any fisheries resource available before his neighbour is able. This ever-increasing fishing effort will only further drive conflicts with dolphins and cause increased bycatch of all vulnerable taxa including sea turtles, while making the lives of fishers increasingly challenging.

Meanwhile small-scale fisheries, the ultimate beneficiaries of the sea, are being squeezed out of high profile “Blue Growth” and “Blue Economy" developments and not accounted for by governance (Cohen et al., 2019). Since fishers are not even obliged to record their landings in North Cyprus, nothing is known about the economic importance of this sector. Fish are imported to North Cyprus from Turkey and farmed fish and foreign fish are displayed in markets with no source labelling. Meanwhile while facing embargos on its own exports, the products of the North Cyprus fishery are largely being exported through the greenline (EU regulation no: 886/2004: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2004R0866:20080627:EN:PDF), the buffer zone that divides the two Cypriot communities, to the Republic of Cyprus where the landing prices of fish are the highest in Europe (GFCM 2016). Be it through top-down or bottom-up approaches, the fiscal rewards (including to fishers and the wider fishing and national economy) of bringing this fishery under sustainable regulation, with managed reserves and sustainable rates of harvest to guarantee long-term yields, surely outweigh the investment required to bring this management about. North Cyprus has an important ecotourism industry. Diving and sea turtles are a huge part of that. Monk seals, seabirds and cetaceans could also become ecotourism flagships. Therfore, although a challenging concept, holistic fisheries management is the best solution for economic and environmental sustainability.

Research priorities

Sea turtles

Onboard observer programmes are needed to assess bycatch rates more thoroughly by region, season and target species/metier. Flipper tagging and satellite telemetry of turtles caught in fisheries should be supported, especially in bycatch hotspots identified by potential observer programs and in migration bottlenecks identified here. The results of such studies would enable the estimation of survival probabilities and provide a greater understanding of how the post-pelagic stage turtles being caught are using habitats in fishing areas and whether there is an ontogenic movement of developing turtles from North Cyprus. Mixed stock analysis (eg. Tikochinski et al., 2018) would be useful in identifying the source rookeries of turtles caught as bycatch in North Cyprus and a bank of samples have been collected through the PhD should the required international collaborations and funding support their analyses.

Dolphins

Our study shows that the bottlenose dolphins using the coast of North Cyprus occur in small groups, but nothing is known about the number of groups and total numbers using the coast. Deployment of static acoustic monitoring devices on fishing gears (as we have shown here that dolphins are far more likely to be detected at CPODs deployed on nets than those deployed on moorings) across the coast could lead to an estimate of a minimum population based on group sizes and simultaneous detections at different sites. Such studies supplemented with targeted onboard observation and photo identification could yield informative results about dolphin behaviour around fishing nets. However, while more powerful acoustic deterrent devices could be trialled, resources could be better spent in exploring management strategies for holistic and sustainable fisheries regulation.

There is still significant marine biodiversity in the coastal waters of North Cyprus, with potential to provided diverse ecosystem services and support blue economies. It is hoped that this thesis has formed an important first step into a research journey that will allow the marine biodiversity of the region to be more sustainably managed.

Appendix I: Questionnaires used in chapter I

Balıkçılık Anketi

Aşağıdaki anket Kıbrıs sahillerinde balıkçılık yaptığınız son 12 aylık sure içerisindeki tecrübeleriniz hakkında bilgi edinmek amacıyla Kuzey Kıbrıs Kaplumbağaları Koruma Cemiyeti (KKKKC) tarafından hazırlanmıştır.

Vereceğiniz tüm bilgiler gizli tutulacak, sadece gerçekleştirilen proje kapsamında genel bilgi edinmek amacıyla kullanılacaktır.

Lütfen aşağıdaki bütün soruları cevaplayın.

<u>Genel Bilgi</u>

1) Adınız nedir?

2. SORUYA GEÇİN

2) Doğum tarihiniz kaçıdır?

3. SORUYA GEÇİN

3) Hangi ülkede doğdunuz?

4. SORUYA GEÇİN

4) Teknenizi nerede tutuyorsunuz?

5. SORUYA GEÇİN

5) Tekneniz kayıtlı mı?

- Evet
- Hayır

6. SORUYA GEÇİN

6) Teknenin adı nedir?

7. SORUYA GEÇİN

7) Teknenin numarası nedir?

8. SORUYA GEÇİN

8) Seyir defteriniz var mı?

- Evet ➡ **9. SORUYA GEÇİN**
- Hayır ➡ **11. SORUYA GEÇİN**

9) Seyir defterinizi control eden biri var mı?

- Evet ➡ **10. SORUYA GEÇİN**
- Hayır ➡ **11. SORUYA GEÇİN**

10) Kim?

11. SORUYA GEÇİN

<u>Balıkçılıkla İlgili Bilgi</u>

11) Genellikle balık avladığınız alanları harita üzerine işaretleyiniz lütfen?

12. SORUYA GEÇİN

12) Son 12 ayı göz önünde bulundurarak; kısacası Mayıs 2009 ayından itibaren, balık avladığınız ayları daire içine alarak işaretleyiniz lütfen:

- Mayıs 2009
- Haziran 2009
- Temmuz 2009
- Ağustos 2009
- Eylül 2009
- Ekim 2009
- Kasım 2009
- Aralık 2009
- Ocak 2010
- Şubat 2010
- Mart 2010
- Nisan 2010
- Mayıs 2010

13. SORUYA GEÇİN

13) Son 12 ayı göz önünde bulundurarak, ayda ortalama kaç kez balık avına (sefere) çıktınız?

- 0 – 10

- 11 - 20
- 21 - 30
- 31 - 40
- 40’dan fazla

14. SORUYA GEÇİN

14) Bu seferler genellikle ne kadar sürdü?

- 6 saatten az
- 7 – 12 saat
- 13 – 24 saat
- 25 – 36 saat
- 37 – 48 saat

15. SORUYA GEÇİN

15) Genellikle, her seferde yaklaşık kaç kilo balık yakaladınız?

- 1kg’dan az
- 1 – 5kg
- 6 – 10kg
- 11 – 15kg
- 16 - 20kg
- 20 - 50kg
- 50kg’dan fazla

16. SORUYA GEÇİN

16) Genellikle, genellikle seferlere kaç kişi ile çıktınız (kendiniz dışında)?

- 1-2
- 3-4
- 5-6
- 6 kişiden fazla

17. SORUYA GEÇİN

<u>Yunuslarla İlgili Bilgi</u>

17) Son 12 ayı göz önünde bulundurarak; kısacası Mayıs 2009 ayından itibaren, balık avlarken yunus gördünüz mü?

- Evet ➔ **18. SORUYA GEÇİN**
- Hayır ➔ **21. SORUYA GEÇİN**

18) En çok yunusa rastladığınız alanları harita üzerine işaretleyiniz lütfen?

19. SORUYA GEÇİN

19) Avlandığınız sırada yunuslar ağlarınıza ya da baragadinize herhangi bir zarar verdi mi?

- Her zaman
- Bazen
- Asla

20. SORUYA GEÇİN

20) Son12 ayı göz önünde bulundurarak; kısacası Mayıs 2009 ayından itibaren, en çok yunusla karşılaştığınız ayları daire içine alarak işaretleyiniz lütfen:

- Mayıs 2009
- Haziran 2009
- Temmuz 2009
- Ağustos 2009
- Eylül 2009

- Ekim 2009
- Kasım 2009
- Aralık 2009
- Ocak 2010
- Şubat 2010
- Mart 2010
- Nisan 2010
- Mayıs 2010

21. SORUYA GEÇİN

21) Genellikle kaç tane yunus gördünüz?

- 0-5
- 6-10
- 11-15
- 16-20
- 20'den fazla

22. SORUYA GEÇİN

22) Son 12 ay içerisinde yunus yakaladınız mı?

- Evet ➡**23. SORUYA GEÇİN**
- Hayır ➡**26. SORUYA GEÇİN**

23) Kaç tane yakaladınız?

24. SORUYA GEÇİN

24) Canlı olarak serbest bıraktınız mı?

25. SORUYA GEÇİN

25) Yunusları en sık hangi tip araçlarla yakaladınız (örneğin, ağ veya baragadi olabilir) (eğer ağla avlandıysa ağ gözü büyüklüğünü de belirtiniz lütfen)?

26. SORUYA GEÇİN

<u>Kaplumbağalarla İlgili Bilgi</u>

26) Son 12 ay içerisinde kaplumbağa yakaladınız mı?

- Evet ➔ **27. SORUYA GEÇİN**
- Hayır ➔ **32. SORUYA GEÇİN**

27) Nasıl yakaladınız?

28. SORUYA GEÇİN

28) Kaçını canlı olarak serbet bıraktınız?

29. SORUYA GEÇİN

29) Kaplumbağaları en sık hangi tip araçlarla yakaladınız (örneğin, ağ veya baragadi olabilir) (eğer ağla avlandıysa ağ gözü büyüklüğünü de belirtiniz lütfen)?

30. SORUYA GEÇİN

30) Kaplumbağaları en çok yakaladığınız bölgeyi haritada işaretlermisiniz lütfen?

31. SORUYA GEÇİN

31) Son12 ayı göz önünde bulundurarak; kısacası Mayıs 2009 ayından itibaren, en çok kaplumbağa yakaladığınız ayları daire içine alarak işaretleyiniz lütfen?

- Mayıs 2009
- Haziran 2009
- Temmuz 2009
- Ağustos 2009
- Eylül 2009
- Ekim 2009
- Kasım 2009
- Aralık 2009
- Ocak 2010
- Şubat 2010
- Mart 2010
- Nisan 2010
- Mayıs 2010

32. SORUYA GEÇİN

<u>Balon Balığıyla İlgili Bilgi</u>

32) Geçtiğimiz son 12 ay boyunca KKTC denizlerindeki balon balığı sayısının arttığını gözlemledik. Bu durum sizing balıkçılık aktivitenizi etkiledi mi?

- Evet ➡ **33. SORUYA GEÇİN**
- Hayır ➡ **34. SORUYA GEÇİN**

33) Sizi nasıl etkiledi?

34. SORUYA GEÇİN

34) Balon balığı yakalamaya ilk olarak ne zaman başladınız?

35. SORUYA GEÇİN

<u>Kuşlarla İlgili Bilgi</u>

35) Son 12 ay içerisinde balık avlarken herhangi bir deniz kuşu yakaladınız mı?

- Evet ➡ **36. SORUYA GEÇİN**
- Hayır ➡ **41. SORUYA GEÇİN**

36) Nasıl yakaladınız?

37. SORUYA GEÇİN

37) Kaçını canlı serbet bıraktınız?

38. SORUYA GEÇİN

38) Bu kuşları en sık hangi tip araçlarla yakaladınız (örneğin, ağ veya baragadi olabilir) (eğer ağla avlandıysa ağ gözü büyüklüğünü de belirtiniz lütfen)?

39. SORUYA GEÇİN

39) Aşağıdaki resimde görülen kuşu hiç yakaladınız mı?

- Evet
- Hayır

40. SORUYA GEÇİN

40) Aşağıdaki resimde görülen kuşu hiç yakaladınız mı?

- Evet
- Hayır

Balıkcılık Projesi Anketi 2

Aşağıdaki sorular Kuzey Kıbrıs Kablumbağıları Koruma Kurumu (SPOT) Biyologları tarafından hazırlanmışdır. Son 12 ayda Kıbrıs çevresinde balık avlarken yaşadığınız tecrübelerinizi öğrenyi arz ediyoruz.

Vereceğiniz her bilgi gizli tutulacak ve sadece proje için kullanılacakdır.

Daha onceki anketlerimizdende anladığımız üzere son yılda Balon balıkları balık avınızı çok tahrip etmiş bulunmaktadır.

Aşağıdaki tabloları sizing kendi bilgilerinize dayanarak, size yakın gelen kutuyu tikleyerek doldurunuz lütfen.

		Kesinlikle katılımıyorum	Katılmıyorum	Bilgim yok	Katılıyorum	Kesinlikle Katılıyorum
1	Balon balıkları şu anda Kıbrıs'lı balıkcıların en buyük tehditidir.					
2	Balon Balıkları en fazla 18mm lik ağlara zarar vermektedir.					
3	Balon Balıkları en fazla 32mm lik ağlara zarar vermektedir.					
4	Balon balıkları ipli ağlara misinalı aplardan daha fazla zarar verir.					
5	Balon balıkları misinalı ağlara ipli aplardan daha fazla zarar verir.					
6	Büyük delikli ağlar suda daha fazla bırakılmaktadır.					
7	32mmlik ağlar gün batımından gün doğuşuna kadar bırakılmaktadır.					
8	18mmlik ağlar sadece gündüzleri kullanılmaktadır.					
9	Büyük balıklar ağda küçük balıklardan daha fazla yaşar.					
10	Balon balıkları küçük balıklara, büyük balıklardan daha fazla saldırmaktadır.					

Düşüncelerimize göre balıkcılar, Balon balıklarının zararlarından kaçmak yerine avlanma yöntemlerini değiştirebilirler. Sizing görüşlerinize göre zaralardan korunmak için;

		Kesinlikle katılımıyorum	Katılmıyorum	Bilgim yok	Katılıyorum	Kesinlikle Katılıyorum
1	Geniş delikli ağ kullanmak.					
2	Baragadi yerine ağ kullanmak.					
3	Derinde avlanmak.					
4	Sığ sularda avlanmak.					
5	Ağları daha kısa süre suda bırakmak.					
Başka görüşleriniz (lütfen açıklayınız):						

Balıklar	Balıkları avlanma zamanınız												Kullandığınız Ağ ölçüleri								
	O	Ş	M	N	M	H	T	A	E	E	K	A	18	20	22	24	26	28	30	32	>32
Barbun																					
Voppa																					
Izmarit																					
Mercan																					
Fangri																					
Karagoz																					
Lagos																					
Orphos																					
Hannoz																					
Berka																					
Mineri																					
Istavrit																					
Izkaroz																					
Iskorpit																					
Sokan																					
Asker																					
Fener																					

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